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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

FORT COLLINS, COLORADO

Raymond Price, Director

U. S. DEPARTMENT OF AGRICULTURE

Forest Service

ANNUAL REPORT

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

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The Station maintains central headquarters at Fort Collins, Colorado, in cooperation with Colorado A & M College

(Not for publication)

C O N T E N T S

RANGE MANAGEMENT RESEARCH

WATERSHED MANAGEMENT RESEARCH

FOREST AND RANGE SOILS

FOREST BIOLOGY

NEW OPPORTUNITIES FOR SERVICE

The year 1955 brought new opportunities for the Rocky Mountain Forest and Range Experiment Station to expand its research service. Through increased appropriations we were enabled to attack a few more of the critical problems that prevent full and sustained use of our water, timber, and forage resources.

The importance of the wild land resources in the Black Hills area was further recognized. As a result, funds were made available for a new research center to develop ways of improving the use and management of these basic resources. Headquarters for the research center were located at Rapid City, South Dakota, in cooperation with the South Dakota School of Mines and Technology. Experienced and well-trained scientists have been recruited, and encouraging progress is already being made on a four-pronged front; namely, forest utilization, timber growth and production, improved range-wildlife habitat, and watershed improvement. This research is being conducted in cooperation with interested State, private, and other Federal agencies.

Of equal importance is the further recognition of the great value of the water resources of the Rocky Mountain Empire. As the Nation develops, streamflow from these mountains becomes increasingly valuable. In keeping with this new emphasis, our research in the Colorado Rockies has been strengthened. For example, we are now studying the influence of alpine snowfields on streamflow. We are also learning how to increase streamflow by testing other possibilities of forest and rangeland management practices.

In central Arizona where the need for increased streamflow is critical, research is being concentrated on how to control the growth and spread of phreatophytes (water-wasting vegetation such as saltcedar) on the upstream water courses.

Another opportunity to demonstrate research values came with the installation of the skyline-crane logging system at the Fraser Experimental Forest in central Colorado. This revolutionary system of logging has several possible advantages. It can tap timber resources on steep, remote slopes that were previously considered inoperable. It eliminates most of the road building and logging damage that usually results from conventional methods; hence, it reduces erosion. By opening up the stands of timber, snowpack may be increased and thus boost water yields.

These new studies supplement the experiments already under way in the eight States served by the Rocky Mountain Station. Notable advances have been made in these going research projects too. Current results from these studies are highlighted in the following pages. A more detailed account of our research findings is released through various official publications. An annotated list of publications issued by the Station in 1955 is included in the bibliography at the end of this report.

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FOREST MANAGEMENT RESEARCH

Highlights of forest management research for 1955 include the following:

Comparison made of growth following three methods of harvesting mature spruce-fir stands

In 1944 a study to determine the silvicultural treatment most suitable in the old-growth spruce-fir type was begun on the Fraser Experimental Forest. The study consisted of four 8-acre plots, three of which were cutover and the fourth left uncut as a control. Sixty percent of the merchantable volume (trees 10 inches d.b.h. and larger) was removed from each of the treated plots in the following manner: (1) Alternate clear-strip cutting -- 50 percent of the volume obtained by clearcutting alternate strips 66 feet wide and 10 percent from a salvage cut in the leave strips; (2) group selection -- 50 percent of the volume obtained by clearcutting circular groups 66 feet in diameter, and 10 percent from a salvage cut in the between-group stand; (3) single-tree selection -- 60 percent of the volume was removed by an individual-tree selection over the entire plot.

Volume per acre in the reserve stand left after cutting averaged 6,465 board-feet per acre for the treated plots. The uncut plot had 17,745 board-feet per acre.

Mean annual growth per acre for 11 years following cutting is shown by treatments in the tabulation below.

Treatment	Annual increment (Bd.-ft. per acre)
Alternate-strip cutting	28
Group selection	46
Single-tree selection	43
Control	116

Increment on the control plot was 3 times the average growth of the 3 treated plots. Since the reserved volume on the check plot was also about 3 times that on the treated plots, there is no evidence that cutting in old-growth spruce-fir stimulates increment in the residual stand.

The smaller increment per acre under strip cutting is due in part to the original stand rather than mortality because mortality was nearly the same on all plots. This plot contained the least volume before logging, was somewhat more open with fewer and smaller sized trees, and had a larger proportion of slower growing lodgepole pine.

Mean annual mortality was nearly the same for all treatments as shown below.

Treatment	Mortality (Bd.-ft. per acre)
Alternate-strip cutting	70
Group selection	61
Single-tree selection	69
Control	72

Previous studies of growth and yield in cutover spruce-fir stands have indicated that average annual mortality per acre is 53 board-feet. The losses from the plots exceeded this estimate 8 to 19 board-feet. Mortality is usually heaviest the first few years after cutting, decreasing as the time since cutting increases. Since the growth and yield studies covered a longer period of time after logging, present results probably reflect early mortality. Subsequent measurements of growth should show a reduced annual mortality when the period after cutting is longer and the cutover plots have had time to develop windfirmness.

Windfall losses accounted for two-thirds or more of the total mortality on the three cutover plots. This is shown below.

Treatment	Average annual loss per acre (Bd.-ft.)	Proportion of loss from all causes (Pct.)
Alternate-strip cutting	47	68
Group selection	40	66
Single-tree selection	60	87

Windfall losses were greatest on the single-tree plot, which was expected. Previous experience with this type of cutting has shown that the relatively shallow-rooted spruce and fir are more susceptible to blowdown when the entire stand is opened up.

Mortality other than windfall on the treated plots was due to insects (spruce beetle), diseases (mostly red ring rot), and such miscellaneous causes as suppression, fire scorch, frost check, porcupines, lightning, and logging damage. Losses from insects and diseases were relatively larger on the strip cutting and group-selection

plots, accounting for 31 percent of the total loss, a condition apparently unrelated to the method of cutting.

Windfall on the control plot accounted for only 10 percent of the total mortality. Blowdown hit scattered trees rather than groups. The uncut stand is thus an almost perfect barrier to the wind.

Insects and diseases (mostly spruce beetle) were responsible for 79 percent of the mortality on the control plot. High insect and disease losses are to be expected in uncut, old-growth spruce-fir stands. Many of the low-vigor trees similar to those logged on the three treated plots are now being killed by insects and diseases on the control plot.

Clearcutting in alternate strips can be recommended rather than group selection as a method of harvesting old-growth spruce-fir stands because windfall can be reduced under strip cutting by (1) increasing the width of the leave strips, and (2) eliminating salvage cutting in the leave strips. Salvage cutting reduces the effectiveness of the leave strips as a wind barrier by opening up the stand too much. The loss of a few trees that would be salvaged before death is too small to offset the increased loss from blowdown.

In addition group selection has a number of disadvantages. They are: (1) It is a difficult and time-consuming system to mark correctly; (2) when the time comes to remove the between-group stand, logs must be skidded through the young stand then growing in the cutover groups; and (3) it is more costly to log per unit of volume. The felling and skidding time is increased because of the nonusable area between groups.

Effect of width and orientation of cutting strips on windfall and regeneration studied

The harvesting of approximately 3 million board-feet of lodgepole pine, Engelmann spruce, and subalpine fir from 550 acres of merchantable timber on the Fool Creek watershed in the Fraser Experimental Forest -- started in July 1954 -- is now 75 percent complete.

Fifty percent of the volume to a 4-inch diameter limit is to be removed by clearcutting in alternate strips. Four widths of strip are used: 1 chain (66 feet), 2 chains (132 feet), 3 chains (198 feet), and 6 chains (398 feet). All strips are laid out at right angles to the contour. Volume removed to date, by products, is shown below.

Products	Volume (Bd.-ft.)
Sawlogs	1,547,700
Poles	982,640
Posts	57,554
Pulpwood	250,000
Total	2,837,894

Not all sub-sawlog material is salable. This is especially true of spruce and fir. Markets exist for pine in the 4- to 10-inch diameter classes as small poles and fence posts. A future market is anticipated for pulpwood. With this expectation, spruce and fir from 4 to 10 inches in diameter (that would be salable as pulpwood) are harvested to determine the silvicultural effect of such cutting on the replacement stand. At present, the pulpwood is being stacked outside the sale area for future disposal.

Studies have been initiated to determine the effect of strip width and direction on windfall and regeneration. Regeneration of lodgepole pine on clearcut areas is generally easy. We know less about how spruce and fir reproduce under clearcutting. Regeneration studies in the spruce-fir type will therefore be given priority.

Blowdown of trees left after cutting is a major problem in both the spruce-fir and lodgepole pine types. A prelogging study of windfall on the Fool Creek watershed has shown that trees are wind-thrown by westerly winds. Strips were laid out in all directions from North-South to East-West, and so can be used to test the effect of strips of different widths oriented at various angles to the direction of destructive winds.

Juniper twig growth closely follows weather conditions

Frequent measurements of twig growth of four native Arizona junipers, during two growing seasons, indicated that growth was closely related to soil temperature and rainfall.

Growth began in the spring when the soil temperature, measured at 3-inch depth in the shade of tree crowns, reached approximately 50° F., and stopped when the soil temperature dropped below this figure in the fall. Growth was most active when soil temperature exceeded 60° F. Initial growth depended on moisture remaining in the soil from winter precipitation, and growth nearly stopped between the time the winter reserve was exhausted and the summer rains began. Summer growth was closely related to summer rain: increases in moisture were reflected in increased rates of twig elongation.

The capacity of native junipers to stop active growth when moisture conditions are unfavorable and to resume growth when moisture is again available may account in part for their ability to survive on dry sites. Seasonal twig growth may also be associated with the formation of false rings which are characteristic in the wood.

More information on possible use of fire in management of ponderosa pine forests

Possible uses of fire in wild-land management in the Southwest have been discussed quite widely in the past few years. The broad interest makes it important to publish facts on possible fire use as rapidly as they are available.

A small-plot test of fire use in ponderosa pine type was set up in 1950 in cooperation with the Bureau of Indian Affairs, Department of the Interior, on the Fort Apache Indian Reservation in Arizona. The results can be summarized briefly as follows:

1. Fire, where it can be properly controlled, may reduce fuel -- dead flammable material of the forest -- without excessive damage to the living forest. However, fire is difficult and expensive to control. This may be especially true in rough topography.

2. Fire "hot" enough to make dead snags out of large living trees may increase rather than decrease the fuel of the forest. Fire, if used at all, should be as "cool" as possible.

3. Fire cannot be controlled precisely enough, with our present knowledge, to thin young trees effectively. Attempts to thin with fire have generally resulted in killing either too many young trees or not enough.

4. Any fire will kill practically all pine seedlings less than 3 to 4 feet high. Fire should not be used where trees of this size are an important part of the forest.

5. Even a "cool" fire reduces density of grass in the forest glades during the year after burning. In more severely burned areas, several years are required for the grass to recover.

Fire use in the ponderosa pine type of the Southwest should definitely be considered as still in the experimental stage.

The Great Plains shelterbelts are reappraised

During 1954 the shelterbelts planted under the Prairie States Forestry Project between 1935 and 1942 were reexamined. The data

were analyzed this past year and complete results will be published soon.

Windbreak effectiveness was classified for a total of 2,738 shelterbelts ranging in age from 13 to 20 years in the "shelterbelt zone" from North Dakota to northern Texas. These included 1,800 shelterbelts in addition to 938 sample shelterbelts first examined in 1944 by Munns and Stoeckeler (see Jour. Forestry 44: 237-257).

Windbreak rating, 1954 (2,738 shelterbelts)

Area	Excellent	Good	Fair	Poor	Destroyed	Total
	- - - - - - - - - percent - - - - - - - - -					
North Dakota	6	44	29	13	8	100
South Dakota	2	36	31	23	8	100
Nebraska	19	37	30	12	2	100
Kansas	10	36	31	15	8	100
Oklahoma-Texas	4	26	31	30	9	100
Average for area	7	35	30	20	8	100

Damage to shelterbelts by livestock use is one of the most serious factors now influencing effectiveness of windbarriers. Heavily grazed shelterbelts lacked density of lower level. The number of sample belts damaged has increased from 8 to 29 percent in the past 10 years.

Sample shelterbelts damaged by livestock

Year	North Dakota	South Dakota	Nebraska	Kansas	Oklahoma-Texas	Region
	- - - - - - - - - - percent - - - - - - - - - -					
1944	2	7	5	7	16	8
1954	22	29	28	27	40	29

Other factors adversely influencing growth and effectiveness of shelterbelts are:

1. Suppression of conifers by broad-crowned, fast-growing deciduous trees in adjacent rows.
2. Snow breakage of conifers resulting from open ineffective shrub rows on north side of belts, from Nebraska northward.
3. Invasion by weeds and sod-forming grasses.
4. Loss of most deciduous species on all upland sites, from prolonged drought in the Southern Plains.

5. Loss of tall, fast-growing deciduous species on upland sites with tight subsoil conditions.

Of the three fast-growing deciduous species used for maximum effective height, Siberian elm proved most versatile. Cottonwood and sycamore survival and height was satisfactory only on lowland sites where water table was within 20 feet, and in depressions of upland subject to concentration of runoff. Siberian elm, on the other hand, had maintained satisfactory survival and height growth on the dry, rolling upland sites, as well as on the better sites.

Site-condition class	Cottonwood		Siberian elm	
	1944	1954	1944	1954
	- Average survival in percent -			
A (good)	66	49	81	73
B	68	39	79	70
C	52	16	77	57
D (poor)	65	10	75	45
	- - Average height in feet - -			
A (good)	22	46	18	36
B	18	40	15	32
C	15	33	12	25
D (poor)	15	28	14	23

Green ash, honey locust, American elm, and burr oak were the best slow-growing deciduous trees on the dry upland sites. Hackberry, though surviving well, was slower in height growth than other comparable species, especially on sandy soils.

Black locust, black walnut, and catalpa gave satisfactory performance only on lowland sites of the central and southern Plains. Average survival of these species on uplands was generally less than 30 percent.

Of the short, fast-growing deciduous species, boxelder in the Dakotas, Russian olive and mulberry in Nebraska and Kansas, and osage orange from Kansas southward all showed satisfactory survival and height growth, as middle-level trees. However, these species, especially Russian olive and mulberry, were frequently used as shrubs on one or both sides of shelterbelts. This has resulted in inadequate protection, because of their tendency to lose lower foliage as they grow older, thus causing the windbreak to become open beneath. In addition, placement of Russian olive as a shrub next to conifer rows has resulted in suppression damage to 32 percent of otherwise good conifer rows in Nebraska.

Site-condition class	Honey locust		Green ash		Hackberry	
	1944	1954	1944	1954	1944	1954
	- - - - Average survival in percent - - - -					
A	82	73	85	77	72	60
B	82	71	86	80	78	69
C	82	65	82	70	75	51
D	83	53	86	76	74	58
	- - - - - Average height in feet - - - - -					
A	13	24	9	20	8	17
B	11	21	8	20	8	16
C	10	18	7	16	7	11
D	12	18	8	13	8	12

American plum, caragana, common lilac, chokecherry, and skunkbush all proved to be excellent shrubs. Tatarian honeysuckle, tamarix, and desertwillow were not satisfactory because of their tendency to grow tall and lose lower foliage.

Of the conifers, eastern redcedar was the hardiest despite suppression, livestock damage, sod competition, and dry sites. Ponderosa pine and Austrian pine appeared well adapted to the drier sites, once established, and averaged taller than eastern redcedar, but initial survival was erratic; 80 percent in some instances, but more often, less than 50 percent. Survival of these three conifers has decreased very little in the past 10 years. Eastern redcedar in the Dakotas survived better than Rocky Mountain redcedar and was twice as tall.

Site-condition class	Eastern redcedar		Rocky Mountain redcedar		Ponderosa pine	
	1944	1954	1944	1954	1944	1954
	- - - - Average survival in percent - - - -					
A	77	73	56	50	42	41
B	73	71	53	49	45	45
C	70	66	35	31	36	36
D	84	81	50	50	60	52
	- - - - - Average height in feet - - - - -					
A	5	14	2	7	3	15
B	4	14	3	8	3	15
C	4	12	2	6	2	12
D	4	13	2	6	3	14

Heavy grazing in shelterbelts results in soil compaction

Samples (in situ) of the surface 2 inches of soil were taken in heavily grazed and ungrazed portions of three 18-year-old shelterbelts in South Dakota. All surface soils were silty clay loam. Samples were taken, in all cases, within the cottonwood rows of the shelterbelt. Less than 10 percent cottonwood survived; but adjoining rows of Siberian and American elm were fairly continuous.

	Shelterbelts			
	1	2	3	All
Average volume weight per unit volume, upper 2 inches of soil:				
Heavily grazed	1.182	1.172	1.312	1.222
Ungrazed	0.888	1.022	1.112	1/ 1.007
Average aeration porosity in percent, upper 2 inches of soil				
Heavily grazed	6.53	9.52	6.72	7.59
Ungrazed	19.00	12.58	10.62	1/ 14.07

Results show highly significant differences in mean volume weight and mean aeration porosity between heavily grazed and ungrazed portions of shelterbelts. Whether or not these differences are sufficient to result in significant differences in infiltration was not determined. Depth of tree litter was variable but always present in the ungrazed portions; it was absent or scattered in heavily grazed portions. Heavily grazed portions were open beneath, lacking shrubs, and swept fairly clear by wind, in contrast to ungrazed portions, which had continuous shrub foliage at the ground level and an accumulation of litter covering the soil surface.

Improved fire-control methods reduce fire losses without increasing costs

Forest fire research is new at this Station, but already it has produced practical results. During 1955 an improved system for rating fire danger, developed during the preceding 18 months as a special project, was used in five southwestern national forests. The system employs two indexes: one, using records of precipitation

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1/ Difference between grazed and ungrazed is highly significant statistically.

and loss of moisture through drying, measures drought conditions; the other, using chiefly wind and temperature observations, measures probable rate of spread of fire. To point up what benefits can result from improved fire-control methods, statistics of several important fire-control parameters for the areas where the two-index system was used in the five demonstrator forests are compared with the same figures for comparable areas in five neighbor forests near the demonstrator forests.

	4-year average	1955	Change
	- - Neighbor forests - -		
Number of fires	526	277	-249
Average size (acres)	3.3	16.6	+13.3
Proportion less than 10 acres (percent)	96.8	96.4	- 0.4
Proportion 10 to 99.9 acres (percent)	2.7	2.2	- 0.5
Proportion 100 acres and larger (percent)	0.5	1.4	+ 0.9
Expenditures for fire protection	$232,969	$392,378	+$159,409
	- - Demonstrator forests - -		
Number of fires	728	428	-300
Average size (acres)	53.3	1.6	-51.7
Proportion less than 10 acres (percent)	95.8	96.5	+ 0.7
Proportion 10 to 99.9 acres (percent)	3.3	3.5	+ 0.2
Proportion 100 acres and larger (percent)	0.9	0.0	- 0.9
Expenditures for fire protection	$641,302	$481,716	-$159,586

There was only one similar trend in both groups: the number of fires in 1955 decreased by about 41 to 47 percent from the average number in 4 preceding years. Burning conditions were generally similar during both periods.

Otherwise, trends were dissimilar. The more important comparisons are: (1) The average size of fires increased appreciably in the neighbor group; whereas it decreased markedly in the demonstrator group; (2) the percentage of large fires (100 acres and larger) almost trebled in the neighbor group, but it dropped to zero in the demonstrator group; and (3) although fire-control expenditures increased appreciably in the neighbor group, they decreased by almost an equal amount in the demonstrator group.

In areas served by the two-index system for rating fire danger in the demonstrator forests, large, disastrous wildfires in timber types were prevented for a year at a saving in fire-control expenditures. Several obstacles precluded efficient performance of the two-index system. During this first year there were not enough fire-danger

stations. Fire-danger stations were not always operated satisfactorily; some fire-control managers were not favorably inclined toward fire-danger rating because of their experiences with other fire-danger rating systems; and fire plans were rather loosely correlated with danger rating.

Nonetheless, the statistics point up that in Arizona and New Mexico, large, disastrous wildfires in timber types probably can be permanently eliminated, or at least greatly reduced in number, and that the job probably can be done with lower expenditures for fire control.

National Forest Survey under way in Station's territory

The national Forest Survey in the Station's mountain States began at midyear. The first project area includes the western slope of the mountains in Colorado, and the southern division of the Medicine Bow National Forest in Wyoming. Gross area is about 9 million acres, of which $5\frac{1}{2}$ million acres is estimated to be commercial forest land. Plans have been perfected and some preliminary field work was done before snow came. Aerial photographs are being made ready so that full scale field work can begin in the spring. About 2 years will be required to complete it.

Field work was completed for the State of Nebraska during 1955. Preliminary calculations show 1.1 million acres of forest land in the State.

Forest management research program launched in the Black Hills

During 1955 the opportunity came to begin research in the Black Hills. Some years ago the Station conducted some limited forest management investigations in that prairie-encircled island of ponderosa pine forest. In recent years the Station could do little more than act in an advisory capacity regarding problems arising in the intensively used timberlands of the Hills. Now past efforts can be reviewed and evaluated, in the new research. Because only about 15,000 of the 1,200,000 forested acres of national-forest land have not had some form of cutting, forestry practices must be geared to second-growth and managed timber.

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FOREST DISEASE RESEARCH

Forest disease research during 1955 continued along two broad aspects; (1) damage appraisal surveys and (2) biological studies. The surveys show what diseases are important to control; the biological studies get the facts necessary to combat them.

A Swiss forester, who has likened an infectious disease to an enemy, stated: "To conquer the enemy it is necessary to know him; in order to know him it is necessary to study him." Forest disease research attempts to do just that.

Damage appraisal surveys show widespread losses caused by dwarfmistletoe

Dwarfmistletoe occurs in 51 percent of the commercial lodgepole pine of Colorado and Wyoming according to surveys completed in 1955. Damage is more severe in cutover than in virgin stands. This suggests that past practices may have favored intensification of the parasite. Regenerated burns are least affected and stands that have arisen in the wake of holocaustic fires are virtually free from infection.

In Arizona and New Mexico there is considerable variation in the abundance of ponderosa pine dwarfmistletoe. According to partially completed surveys, it infests 51 percent of the commercial stands in northern Arizona, 54 percent in southwestern New Mexico, and 23 percent in the northeastern part of that state. The low incidence in northeastern New Mexico could very well be the result of heavy cutting in the railroad logging period during which the dwarfmistletoe population may have been sharply reduced. The parasite was relatively more abundant on Douglas-fir than on ponderosa pine, although the attendent losses in Douglas-fir are considerably lower in timber values.

New facts on dwarfmistletoe seeds

Germination-infection studies of ponderosa pine dwarfmistletoe indicate that seeds planted on the current year's growth give rise to shoots sooner than those on older growth. There are marked local differences in degree of successful artificial infection. On one study plot in a naturally infected stand, 10 percent of the seeds led to infection; another plot in a dwarfmistletoe free stand

about a mile away, infection amounted to only 1 percent. Differences between these two plots were also expressed in the length of time required for shoot appearance, a minimum of 2 years on the first plot, 5 years on the second. Since germination percentages were about the same, these differences appear to be associated with establishment of infections in the host rather than in seed viability.

Preliminary studies of seed dispersal of ponderosa pine dwarfmistletoe were started this year. They showed that the period of seed dispersal lasted about 30 days, but more than 90 percent of the seeds were expelled during a 2-week period beginning July 28. Peak discharge came on August 4.

New study shows growth loss due to dwarfmistletoe

Analysis of 540 ponderosa pine increment cores collected on the Mescalero-Apache Reservation in 1952, revealed marked reductions in radial growth of heavily infected dominants in the last 5 years. Periodic growth of infected trees was 68 percent of healthy trees in 50-year-old poles; only 40 percent in 140-year-old merchantable stands. Growth rate was directly correlated with intensity of infection, but marked reductions were apparent only where dwarfmistletoe was present in more than half of the crown.

Research on methods for controlling dwarfmistletoe were continued

Examinations of two 10-acre experimental control plots in ponderosa pine (established by the Bureau of Indian Affairs on the Mescalero-Apache Reservation in New Mexico) revealed that the number of infected trees has increased markedly in the past decade. On 1 plot in which all heavily infected merchantable-sized trees had been cut in 1945 and only 10 lightly infected trees left, 58 of the overstory trees were infected in 1955.

Reexamination of permanent plots on the South Rim of the Grand Canyon indicated that the incidence of dwarfmistletoe in trees larger than 2 inches d.b.h. had increased 5 percent in the last 5 years on untreated check plots. On one of these plots the total living basal area dropped from 46.3 to 41.3 square feet in the 5-year period. It is still too early to compare the effects of control with the deterioration of diseased natural stands in this control area, but reexamination has provided information on the relative effectiveness of direct control measures.

The results of chemical control tests with ponderosa pine dwarfmistletoe suggest that some trunk injections (boric acid as well as 2,4-D) may have a marked selective effect on dwarfmistletoe.

This method might have some value in administrative, scenic, or recreational areas, but would be of limited application in timber-producing areas.

At least 6 insects (several species of Lepidoptera) have been observed causing considerable damage to dwarfmistletoe shoots. These insects will be studied further in cooperation with Forest Insect Research.

Emphasis in red rot research shifted to cutover stands

Past research has provided estimates on the regional distribution of red rot and its economic importance in old-growth ponderosa pine and has led to the development of indirect control methods. However, a practical evaluation of the rot problem in residual and second-growth stands under management is still needed. As evident from available data, the losses in cutover stands will depend largely on the extent to which decayed trees are removed in the initial cuts. Light improvement-selection or salvage-type marking currently being practiced tends to retain older decayed trees provided they have a life expectancy of at least 20 years. These trees may contribute materially to red rot cull in second and subsequent cuts. Because of the widespread interest of forest administrators in this question, a preliminary study was started in 1955 on the Defiance Logging Unit of the Navajo Indian Reservation, in cooperation with the Bureau of Indian Affairs and the Navajo Tribal Council.

Results of inoculations with the red rot fungus are encouraging

Inoculation tests were begun with the red rot fungus (P. anceps) in 1953. The ultimate objectives of the tests are to determine the factors affecting establishment and rate of decay, and to study races of the fungus and natural resistance of the host. Since the fungus rarely if ever develops on exposed wood, but invariably attacks living trees by first decaying bark-covered dead branches, the major emphasis in preliminary tests was placed on developing suitable techniques for starting branch decay. All branches inoculated in 1953 have been collected and studied in the laboratory. The red rot fungus was not active in any of the 7 inoculations collected in 1954, but it had caused some decay in 14 of the 18 collected in 1955. From these limited results it is apparent that the fungus revives after long dry periods when moisture conditions in the branches become favorable. After 2 years there were no significant differences between 5 isolates used. Best results were obtained in recently dead branches. Inoculations of branches with cracked and loosened bark gave poor results. Positive inoculations of living branches suggest that P. anceps is weakly parasitic, a tendency that has been observed in natural infections.

This characteristic was also evident in several bole inoculations made in 1953 in which inoculum was placed in holes bored through knots of young trees that did not contain heartwood. Examination of inoculations made in 1954 again revealed little evidence of fungus activity after 1 year, but it is expected that the heavy summer rainfall in 1955 resulted in a revival of the fungus in most cases. Additional inoculations were made in 1955.

Indian paintbrush successfully inoculated with spores of the limb rust fungus

Disease losses in southwestern ponderosa pine caused by the limb rust fungus (Cronartium filamentosum) are probably exceeded only by those from dwarfmistletoe and red rot. Eventual control practices will hinge on the imperfectly known host relationships of this fungus.

In 1952, a Cronartium on Indian paintbrush was found associated with ponderosa pine bearing the aecial stage of the limb rust fungus (C. filamentosum) at Grand Canyon National Park. Subsequent observations at several other points in Arizona and New Mexico revealed that the association of rust-infected Indian paintbrush and ponderosa pine was relatively widespread. To determine the host relationships of C. filamentosum experimentally, inoculations of Castilleja sp. were made in 1953, but they yielded no results because the host plants died. New experiments were made in 1955 using aecial material from the Santa Fe National Forest and Castilleja austromontana from the Manzano Mountains of the Cibola National Forest.

Wilding Castilleja transplants were inoculated with rust spores from pine. Infections developed in 36 percent of the inoculated plants but all the check plants remained rust free. Additional tests will be conducted (1) to determine the susceptibility of other species of paintbrush, (2) to return the rust from paintbrush to pine, and (3) to find out whether the rust can go directly from pine to pine.

Studies of Colorado aspen diseases continue

Canker diseases and heart rots cause heavy annual losses in aspen. Three distinct types of cankers of unknown or uncertain cause have been recognized. Work was started this year to determine the organisms and the environmental conditions responsible for them. A fourth canker caused by Hypoxylon pruinatum was observed for the first time in Colorado. This canker is a serious disease in the Lake States.

Six additional plots cut for decay analyses reemphasized the wide variation in decay within an age class. Present indications are that stand history may have an important bearing on the amount of decay to be expected in merchantable sizes.

Windfall of beetle-killed spruce increases

Tallies at 2-year intervals on beetle-killed spruce study plots on the White River National Forest showed that 7 percent of the trees have fallen since the start of the study in 1951; 2 percent in the first 2 years and 5 percent in the last 2. Windfall appears to be linked with the development of two brown rots (Fomes pinicola and Coniophora puteana), which cause the trees to break at or just above the groundline. Root rots have been relatively unimportant thus far in contributing to blowdown.

Identification of wood-rotting fungi continued

Work on the identification of heart-rotting fungi was continued during the year. This research has made it a relatively simple matter to recognize the more common heart rots in the subalpine types of Colorado. The Station was fortunate in having several weeks assistance from Dr. J. L. Lowe, Professor of Forest Pathology at the New York State University, College of Forestry. With his help as a collaborator, 320 collections of decay in dead subalpine timber species were made. Cultures of the more common fungi identified to date include: Poria anierina, P. albobrunnea, P. asiatica, P. bombycina, P. lenis, P. notata, P. rixosa, P. sinuosa, P. subincarnata, and P. vaillantii.

Heart rots of subalpine fir analyzed

Recent studies of decay in subalpine fir (Abies lasiocarpa) and corkbark fir (A. lasiocarpa var. Arizonia) in Colorado indicate that rot losses in living trees are negligible up to 100 years of age, but losses increase rapidly in the second century. The proportion of trees with butt rot after age 100 was surprisingly high, ranging from 59 percent in the 100-149 year-old class to 85 percent in trees older than 300 years. On a d.b.h. basis, butt rot was found in 44 percent of the 7-inch trees and increased steadily in the larger sizes to 93 percent in the 17-inch class and finally 100 percent at 21 inches and larger. The proportion of trees with trunk rot, which is primarily responsible for volume losses in standing timber, was about half that for butt rot in both age and diameter comparisons. No quantitative information is available on the effect rot may have on windfall; this point must be ultimately considered in developing a disease control program for subalpine fir. Of 208 separate rot infections studied for courts of entrance,

60 percent came in through roots, 17 percent through trunk and basal wounds, 12 percent through branch stubs, 10 percent through broken tops, and less than 1 percent through frost cracks and/or cankers.

Of the 17 or more fungi responsible for decay, Stereum sanguinolentum was far ahead of all others in frequency and volume. The Indian paint fungus (Echinodontium tinctorum), which causes severe losses in A. lasiocarpa in British Columbia and in other species of fir throughout the West, including white fir (A. concolor) in Colorado, has never been found on subalpine fir in Colorado.

New or threatening diseases need further study

The cause of "tip burn" of ponderosa pine on the Prescott National Forest remains unknown. The diseased area now covers about 1,200 acres, and checks are being made to determine whether it is increasing in size.

Broom rusts of spruce and fir caused by Melampsorella cerastii (Peridermium coloradense) heretofore considered of botanical interest only, appear to be indirectly responsible for severe breakage in Engelmann spruce; in addition to causing losses directly, they create ideal breeding places for the Engelmann spruce beetle.

Increasing values of lodgepole pine as a timber species have focused attention on the need for reducing damage from hip canker and other rusts that have long been known but hardly studied in connection with the pathology of this species.

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FOREST INSECT RESEARCH

Forest Insect Research is concerned with each of the four steps in control of insect infestations, namely: (1) Detection of incipient outbreaks, (2) appraisal of the outbreak to determine if it is increasing, static, or decreasing, and to select methods of control, (3) execution of the control plan, and (4) survey of results to determine additional control needs.

In detection, step 1, we are concerned with improvement of the methods, training of observers, coordination of reports, and inspection of infestation.

An adequate appraisal, step 2, not only includes delineation and measurement of the damage but also an appraisal of the natural control forces such as insect parasites and predators, insectivorous birds, diseases, climate and weather, and host and stand susceptibility. The control methods and plans are then based upon the findings.

Our part in the execution of the control plan, step 3, includes training in techniques, checking for effectiveness of treatment, and checking the natural control forces as they affect control plans.

We are interested in the results, step 4, because herein lies the test of the accuracy of the appraisal survey and the adequacy of the control method.

Information obtained during 1955 that relate to these activities includes the following.

Forest insect conditions in the central Rocky Mountains

Two major forest insect pests, the Engelmann spruce beetle and the Black Hills beetle, in general declined from epidemic to endemic levels during 1955 in the central Rockies. Three other potentially dangerous forest insects, the Douglas-fir beetle, the Great Basin tent caterpillar, and the spruce budworm, increased in numbers and destructiveness. The mountain pine beetle, too, was observed to be at an epidemic level in a small area on the Shoshone National Forest in Wyoming.

The chemical treating and logging of 325,844 Engelmann spruce beetle-infested trees on the Uncompahgre-San Juan control project during 1955 has reduced the outbreak to a mopup phase. The prediction for next year is that the control work on the project will be relatively less than in 1955; a maximum of 25,000 trees will need to be treated. Small outbreaks of the spruce beetle in other parts of Colorado may require a limited amount of control.

A spruce blowdown over an estimated gross area of 200,000 acres on the San Juan National Forest east of the Uncompahgre-San Juan control project area occurred in November 1954. Permanent study plots were established and a systematic survey of the area was completed in November 1955. The spruce beetle attacks on the broken and uprooted trees thus far are extremely light, but the situation will continue to be hazardous from the standpoint of spruce beetle buildup for several years. The trend of the beetle populations in this area will be kept under observation.

Black Hills beetle activity in Colorado, Wyoming, and South Dakota has declined; only 5,655 trees are estimated for treatment in 1956. Of an estimated 9,705 trees attacked in 1954, only 3,480 actually required treatment in 1955. An increase in natural control was largely responsible for that reduction.

Tree killing by the Douglas-fir beetle has been observed on the San Juan and White River National Forests. Studies are being initiated to develop a satisfactory survey method so a more accurate appraisal of damage can be made.

Two defoliators, the spruce budworm on fir and Douglas-fir and the Great Basin tent caterpillar on aspen, are increasing. As yet no tree mortality by the budworm has been observed. The tent caterpillar has caused widespread tree killing in southern Colorado, but the most serious aspect of this epidemic is the reduction in the aesthetic value of summer home sites and picnic areas in the aspen type. About 1,600 acres out of the 141,000 infested acres were sprayed with DDT by airplane. Plans are being made to increase the acreage in the 1956 spray program.

The poplar and willow borer, Cryptorhynchus lapathi, is in outbreak proportions in the Black Hills of South Dakota. It is weakening and killing willow throughout the area. This exotic insect was reported from the Black Hills about 1952. The extent and age of damage indicates an introduction around 1945.

Summary of control planned for 1956

	Number of trees
Engelmann spruce beetle	
Arapaho National Forest	100
White River National Forest	1,000
Uncompahgre-San Juan Project	25,000
Black Hills beetle	
Bighorn National Forest (cooperative project)	125
Black Hills National Forest	1,060
Pike National Forest	350
Roosevelt National Forest	2,000
San Juan National Forest	770
San Isabel National Forest	1,350
Great Basin tent caterpillar	
San Isabel National Forest (cooperative project)	5,000+ acres

Forest insect conditions in New Mexico and Arizona

Ponderosa pine mortality caused by the southwestern and roundheaded pine beetles in association with drought continued to be heavy in 1955. The threat by the spruce budworm to Douglas-fir and true firs was reduced by a large control project. The status of these three pests and others and control accomplishments are briefly summarized in the following paragraphs.

Infestations of the southern pine beetle, Dendroctonus barberi Hopk., and the roundheaded pine beetle, D. convexifrons Hopk., are widespread over Arizona and New Mexico. Infestations are especially heavy on Bandelier National Monument and the Los Alamos Withdrawal Area. An estimated 6,000 trees were killed by the insects and associated Ips. sp. Similar infestations broke out on the Apache National Forest near Springerville, Arizona, and the Cibola National Forest near Magdalena, New Mexico. The infestations are associated with severe drouth in many forest areas.

During June and July 1955, spruce budworm infestations on 446,611 acres on the Santa Fe, Carson, Cibola, and Lincoln National Forests were treated by the aerial application of DDT. On the average, approximately 90 percent of the budworms were killed by the treatment.

Another 400,000 acres of spruce budworm infestation in the region still needs treatment. With the exception of epidemics on the Kaibab National Forest, Grand Canyon National Park, the Navajo Indian Reservation, and the Cibola National Forest, much of the infestation is on private lands and wilderness areas. The named areas have been recommended for treatment in 1956.

The fir engraver beetle, Scolytus ventralis, which has killed about 80 percent of the white fir stands in the Sandia Mountains, has sharply decreased during the past year. Tree-killing is especially heavy in the Sandia Crest Recreational Area. Heavy rains during the summer months may have been responsible for the sudden decline of the infestation.

An incipient outbreak of the Black Hills beetle, which killed approximately 1,000 trees on the Chuska Unit of the Navajo Indian Reservation in 1954, was successfully controlled in June and July of 1955. Infested trees were felled, bucked into sections and sprayed with a water emulsion of ethylene dibromide. Post control surveys indicate that it will be necessary to treat 100 trees in 1956.

A parasite of Engelmann spruce beetle was studied

Work designed to develop a method of mass rearing of Engelmann spruce beetle parasite, Coeloides dendroctoni, is giving encouraging results. The parasite was successfully reared from the spruce engraver, Ips pilifrons. Techniques for mass rearing are yet to be developed. Pertinent findings of life history field studies of the parasite are (1) they produce one generation a year; some individuals, however, are able to produce two generations, and (2) most individuals require a period of severe cold to break the larval diapause in the cocoons.

Engelmann spruce beetle biology was continued

Engelmann spruce beetles began to emerge to hibernate beneath the bark at the base of the tree in early August, or about 3 weeks later than in 1954. This later emergence was expected because the spring of 1955 was much colder than the spring of 1954.

Field counts of eggs deposited per inch of gallery in the epidemic area in southwestern Colorado for use in vigor-strain studies and for comparison with similar counts several years ago in the epidemic area in northern Colorado, indicates little difference in beetle fecundity. Approximately 20 eggs per inch of gallery were laid by beetles in northern Colorado compared with approximately 17 and 18 eggs per inch in 1955 in two widely separated locations in southwestern Colorado.

Infestation trend of Engelmann spruce beetle correlated with beetle density in bark

The classification of an infestation of the Engelmann spruce beetle on the basis of whether the number of infested trees can be expected to increase, decrease, or remain static is closely correlated with beetle numbers per square foot of bark at $4\frac{1}{2}$ feet above the ground just before the beetles go into hibernation. Beetle numbers in turn are closely correlated with predation and the amount of bark removed by woodpeckers.

Early returns from a long-term study to gather information that can be used for forecasting the course of an infestation and for making decisions on control are presented in the table below:

Plot	No. Trees	Beetles per sq. ft. (mostly callow)	No. of trees showing heavy woodpecker activity	Infestation class
1	25	1	22	Decreasing
2	25	10	10	Static
3	25	1	20	Decreasing
4	25	14	22	Increasing
5	25	70	5	Increasing
6	10	37	2	Increasing

Trap trees are practical as a supplemental measure in Engelmann spruce beetle control

Trap trees (felled green trees) were sampled in 5 areas to determine their attractiveness and effectiveness. Results confirmed the observations over the past several years. Groups of traps apparently should not be more than one-half mile apart to control infestations effectively. As the distance from the trap trees increases, the number of standing trees attacked becomes greater. Also, care must be taken to cut enough trap trees. Even in areas containing moderate to heavy woodpecker activity, 1 trap tree should be felled for every 4 to 5 infested standing trees containing insects of the generation that will attack the traps. Where less woodpecker activity is present, more trap trees should be felled.

Trap trees felled in the fall absorbed about twice the number of Engelmann spruce beetles as those felled in the spring. This observation was made on the San Juan National Forest where trees were felled in October 1954 and in June 1955.

Another observation on the San Juan National Forest concerned standing trees as traps. In one area trap trees were felled and additional trees were hack-girdled. After beetle flight, data were collected from the felled trees, the girdled trees, and green trees that had been attacked. The felled trees, as usual, were effective traps. The standing girdled trees, however, absorbed no more beetles than any other standing attacked tree. Moreover, some of the attacks on the girdled trees were extremely light.

Logging operation attracts Engelmann spruce beetles

With the use of radioisotopes, we are learning much about the flight habits of the Engelmann spruce beetle--how far, how rapidly, and the direction infestations spread, and where to place trap trees for maximum efficiency in collecting beetles. This year a new isotope, iridium 192, was used because of its greater half-life than iodine 131. The beetles were immersed in solutions of the radioisotopes, dried, and released. The radioisotope crystals cling to the body of the beetles and emit gamma rays, which penetrate the bark and are registered upon a scintillation counter. In this manner, the tagged beetles can be relocated after they have made their flight and bored beneath the bark of trees or logs.

The findings showed that (1) an active logging operation one mile from one of the release points strongly attracted the beetles, few beetles were relocated at intervening points, and (2) green spruce logs, ordinarily very attractive to beetles, received no attacks by tagged beetles when located in meadows; the beetles flew over these logs to felled trees in spruce stands as far as 3 miles from the release point.

New emulsifiers suitable for ethylene dibromide

Tests reveal that blends of the new Tritons X-171 and X-151 (Rohm and Haas) are more effective emulsifiers for ethylene dibromide emulsions than the blend of Tritons X-100 and B-1956 for use in the bark beetle chemical control formulation. Their pour points are considerably lower, a very important factor where proportions must be measured during cold weather at field mixing plants. The cost of X-151 is approximately half that of B-1956 (each functions as the oil-soluble component of the respective emulsifier blends); X-171 and X-100 are about equal in cost.

Studies on the polyhedrosis virus of the Great Basin tent caterpillar are encouraging

Treatment of the Great Basin tent caterpillar with a small amount of polyhedrosis virus on the Carson National Forest resulted in the recovery of enough virus to treat approximately 1,000 acres of aspen infested with the caterpillar. The original application was to trees covering somewhat less than an acre.

The life history of the insect is considerably different from that in California. The caterpillar stage in Arizona and New Mexico extends over a period of approximately 30 days. In California the larval period is 60-70 days.

Tree mortality from extensive continued defoliation by the insects is becoming prevalent over the northern part of New Mexico. Tree mortality is threatened in scattered stands covering several thousand acres.

Nematode parasites of the eastern spruce beetle and southwestern pine beetle

In a search for new kinds of parasites of bark beetles, living adults of eastern spruce beetle, Dendroctonus piceaperda, from Lake Sturgeon, Ontario, were examined for internal nematodes. Eighteen percent of the beetles were infested with Aphelenchulus reversus Thorne, a common species. Most of the specimens contained Rhabditis sp., which infests the gut and is probably harmless.

Three percent of the Southwestern pine beetles, Dendroctonus barberi, examined from New Mexico were infested with Aphelenchulus sp. probably new. The species from D. barberi is closely related to one from D. brevicomis and D. frontalis. Its effect on its host is not known, but it is thought to be similar to that of A. reversus.

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FOREST UTILIZATION RESEARCH

The aims of forest utilization research are to broaden and improve present wood-harvesting and utilization practices and to encourage the establishment of new industries needed to utilize the raw materials produced by our forests. Research was expanded during the past year with the installation and testing of a skyline logging crane on the Fraser Experimental Forest, and with the establishment of a new research center in the Black Hills. Results and progress made during 1955 are as follows:

Skyline-crane for logging high-altitude, steep-slope timber tested

An overhead cable system for logging steep, remote timberlands is being tested on the Fraser Experimental Forest in Colorado. Overhead cable logging makes possible management of large areas of forest land previously considered inoperable. Harvesting these idle forest stands not only permits the utilization of wood which otherwise might be lost to insects, disease, decay, or old age, but fosters the advent of forest and watershed management for high-altitude, steep-slope timberlands. Removal of these forests in prescribed cutting patterns will improve forest growth and increase the snowpack available for water yield.

A W-30 Wyssen Skyline-Crane of 2-ton capacity was installed during the latter part of July on West St. Louis Creek about 3 miles from the Fraser Experimental Forest Headquarters. The accompanying sketch shows a diagrammatic layout of the logging system.

The cutting strip was one-half mile long, 330 feet wide, and included an estimated 160,000 board-feet of spruce-fir timber. Engelmann spruce made up 90 percent of the total volume. Slopes varied from 30 to 80 percent with an average of 50 percent.

Logging began August 4 and continued for 7 weeks with time out for frequent demonstrations. During this period a total net volume of 128,000 board-feet was delivered to the landing. More than 79,000 board-feet were delivered during the final 14 days of logging. Only 5 men were used on the logging crew.

Estimates made prior to the test showed that total costs for skidding and yarding would be $16 per thousand board-feet net log

scale. Actual costs differed from anticipated costs, but for the period under analysis the difference was less than expected.

Preliminary summary of performance and costs for the 14-day logging period is given in the following tabulation.

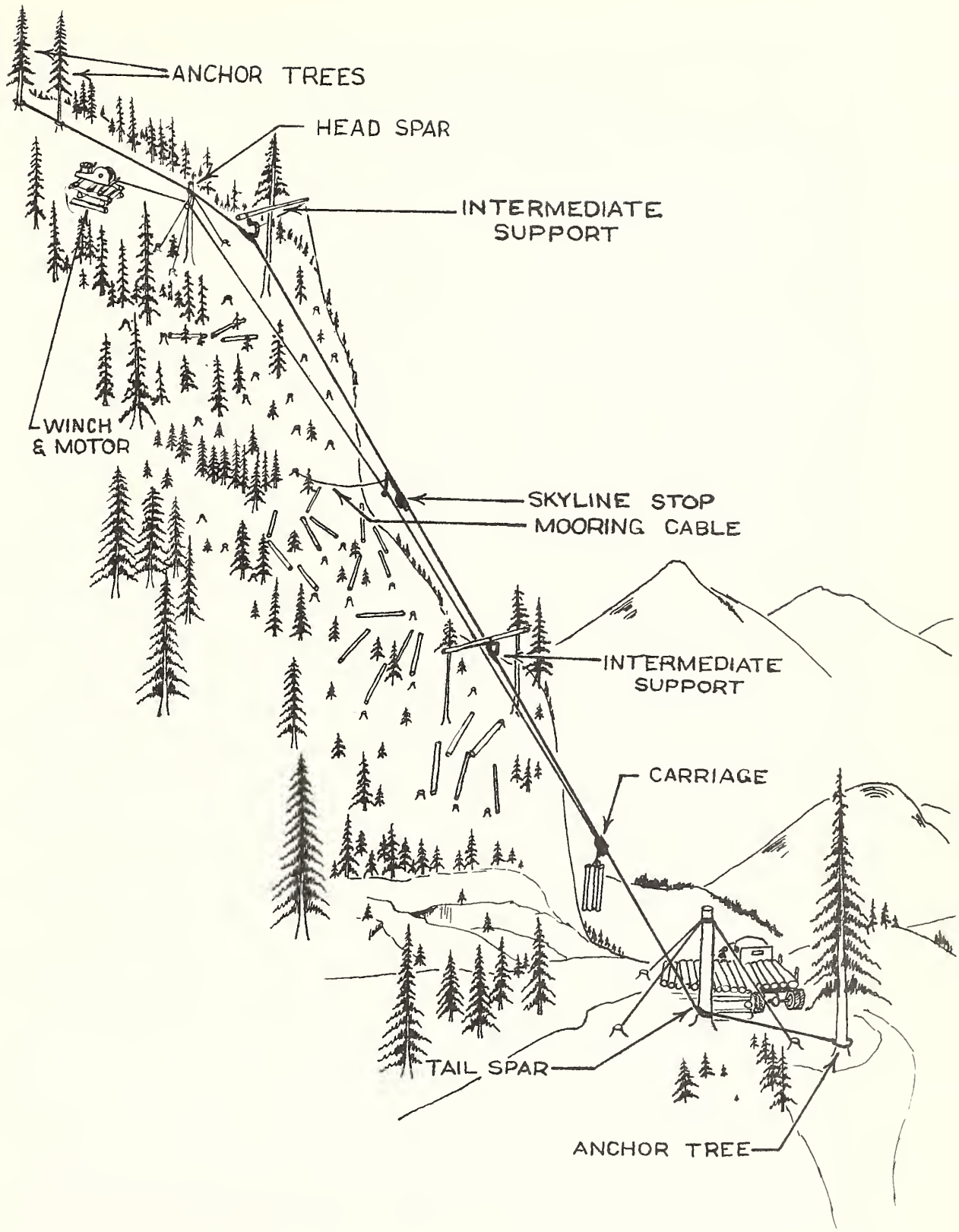
Productive crew hours[2/] per 8-hour day	5.8 hours
Average volume skidded and yarded per productive crew hour	982 board-feet
Average number of logs per 1,000 board-feet.	13 logs
Operating costs per 1,000 board-feet:	
Labor	$ 7.14
Gasoline, oil, and lubricants	.22
Reserve supply fund	3.00
(includes a parts replacement account)	
Depreciation	1.00
Total	$11.36

Labor cost of $7.14 per 1,000 board-feet was determined by using productive crew hours and net log volume. If the more realistic labor cost of $8.84 is used, which includes charges for total crew time on the logging site, the total operating cost becomes $13.06 per thousand board-feet.

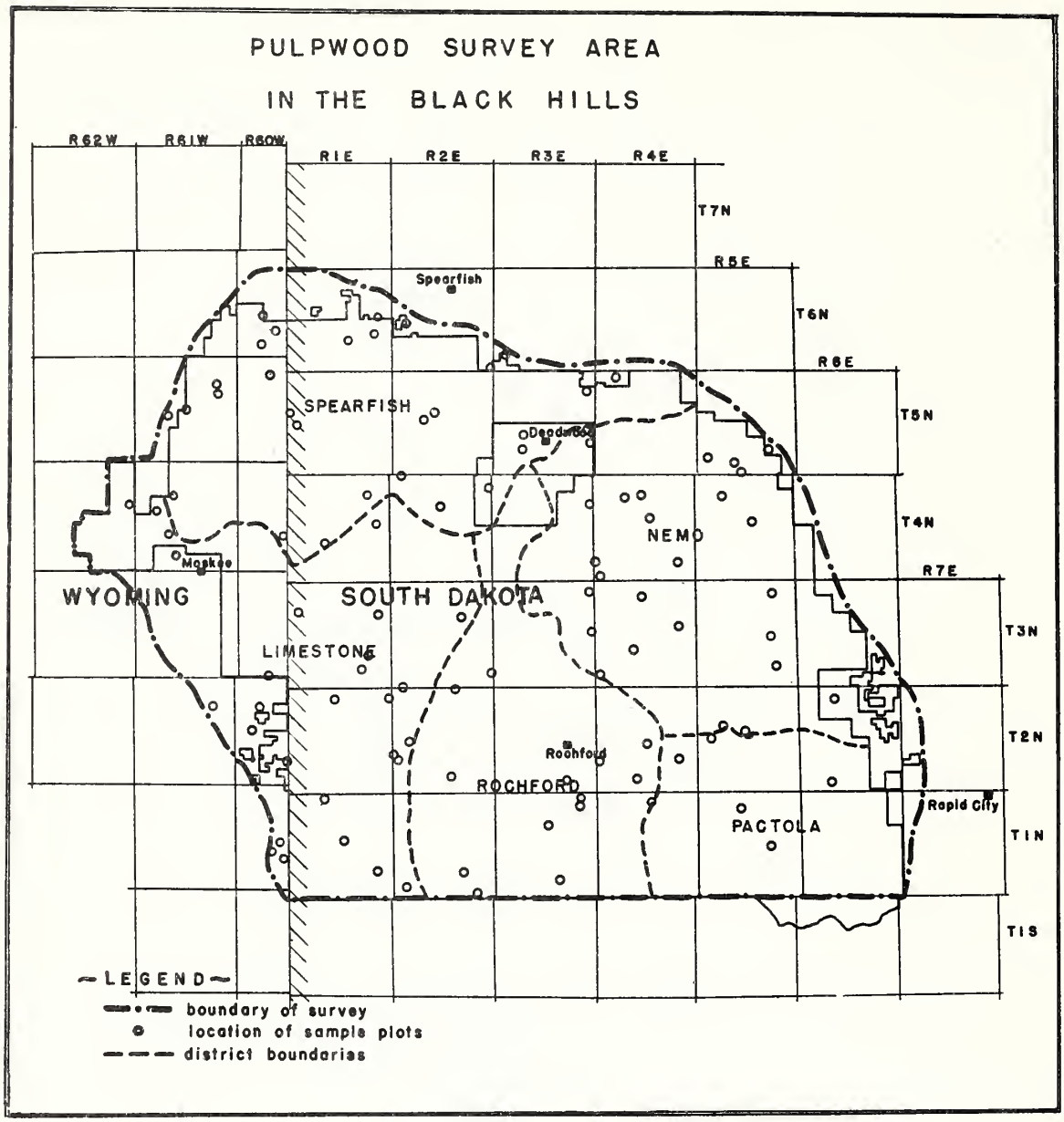
Cost of labor for installation was not included in this summary. A well-trained crew should be able to install the equipment in 3 to 4 crew days. Cost per thousand board-feet would vary inversely with the volume logged per setting; e.g., an installation cost for 4 crew days at $70 per day on a 150,000 board-foot setting would be $1.86 per thousand board-feet delivered to the landing, while on a 250,000 board-foot setting the cost would be $1.12 per thousand board-feet.

Total costs of logging determined from the foregoing tabulation demonstrates the economic feasibility of overhead cable logging in Rocky Mountain conditions. Additional testing on the Fraser Experimental Forest next season and possibly at other points in the Rockies during succeeding years will further refine cost data for skyline-crane operation.

2/ Actual time during which productive logging was conducted. Time spent for car travel and shutdowns for demonstrations and maintenance not included.



General layout of skyline-crane overhead cable logging system



Black Hills ponderosa pine pulpwood being tested by Lake States pulp and paper mills

Several hundred cords of ponderosa pine pulpwood from the Black Hills stands were purchased by a number of the Lake States mills for test purposes. The main object of the tests is to determine the economics of shipping pulpwood from the Black Hills and to provide a basis for comparing the costs with those of present sources of supply. Special consideration will therefore be given to yields of pulp obtained per unit of wood. In view of the relatively thick bark of ponderosa pine, bark content will be a critical item and will likely receive most attention. Both peeled and unpeeled material is included in the study.

Ponderosa pine stands in northern Black Hills can support 50-ton groundwood pulpmill

A survey made of the ponderosa pine stands in the northern Black Hills (see accompanying map) showed that there was sufficient pulpwood presently available to support a 50-ton groundwood pulpmill. The survey was made because of strong local interest in the establishment of a pulpmill in the general area. The information was also needed to inform other pulp and paper producers on amount of raw material available.

The highlight of the survey, which is being published as a Station Paper, was that sufficient pulpwood is available on operable areas -- areas that will yield at least 6 cords per acre -- to support a 50-ton mill for 67 years. This does not include the additional volume that would become available through growth, which in all probability would perpetuate the supply. All volumes considered are over and above the stocking required for maximum sawtimber production.

Pulpwood survey shows that northern Arizona forests can sustain daily production of approximately 1,000 cords

To meet the increasing demands for information on the volume of pulpwood available in Arizona, a survey was made of the major timber-producing areas. The survey included the volume of material available from growing stock and from the most usable and accessible logging and milling residues available in the area. The results showed that a total production of approximately 1,000 cords per day could be sustained from the following sources:

	Cords
Growing stock	183,000
Logging residue	57,000
Milling residue	78,000

The volume determined from growing stock did not include similar material available on adjoining other public lands. The volume shown is over and above the amount required for sawtimber production and includes all species in the area.

The amount shown for logging residue includes only the most suitable portions of the tops and trunks. Expressed in terms of volume per thousand board-feet of sawlogs cut, the amount of pulpwood in the mature ponderosa pine type was approximately 17 cubic-feet, or about 0.24 cord (based on solid cord content of 70 cubic-feet). The volume varied with tree diameter as shown in the following breakdown:

Tree d.b.h. (inches)	Pulpwood volume per M bd.-ft. of sawlogs (cu.-ft.)	(cords)
10 to 20	40.8	0.58
21 to 30	16.4	.21
31+	16.1	.20
Average, all diameters	17.0	.24

The volume of milling residue shown as available was based on the conversion factor of one-half cord, or approximately 1,000 pounds (dry basis) per thousand board-feet of sawlogs cut.

Results of the survey were processed for publication by Region 3 of the Forest Service. The report is entitled, "Possibilities of Pulpwood Production from the National Forests in Northern Arizona."

Analysis of lumber-grade recovery from ponderosa pine confirms preliminary findings

An analysis of lumber-grade recovery from ponderosa pine in the Black Hills was completed. The information is being processed for publication as a Station Paper. Results verified the earlier estimate of overrun and grade recovery. Overrun of as much as 35 percent can be expected when short, 6-foot lumber is produced. Regression analysis failed to show any measurable influence of site, log length, log position, or apparent log grade on overrun. It did show that a significant correlation existed between gross volume and lumber tally. The average overrun for logs ranging in diameter from 7 inches to 22 inches and from 10 feet to 16 feet long equalled approximately 14 board-feet per log. When good sawing practices are carefully followed, reasonable recovery of high-grade lumber -- 13 percent -- can be obtained from the timber. As would be expected, the recovery of select-grade lumber increased directly with log and tree diameter. Losses from seasoning were small and accounted for only 1 percent by volume.

Fifty percent of log volume converted to lumber

A study of the sawmill residue (sawdust, slabs, trim, edgings, etc.) was made in conjunction with the lumber-recovery study of Black Hills ponderosa pine. The results of the study were published as Research Note No. 17, "An Estimate of Residue at a Small Sawmill in the Black Hills." The following tabulation summarizes the volume of residues and lumber produced per thousand board-feet net log scale (Scribner decimal C).

	Volume per M bd.-ft. (cu.-ft.)	Percent of total
Slabs	24.3	11
Edging	10.9	5
Trim	13.4	6
Total solid residue	48.6	21
Total sawdust	63.7	28
Total residues	112.3	49
Total lumber	115.0	51
Total volume	227.3	100

An overrun of 35 percent was obtained. This reflects better than average care in holding waste to a minimum and in getting the maximum lumber volume from the logs.

Annual paper requirements of nine States estimated at approximately 27 million tons

To provide a base for planning for the pulp and paper manufacturing capacity in the area, the annual paper requirements for a nine-State area was studied. The States included were Arizona, New Mexico, Colorado, Wyoming, Kansas, South Dakota, Nebraska, Oklahoma, and West Texas. The results of the study were published in Research Note No. 18, "Estimated Paper Consumption in Nine Central Rocky Mountain and Plains States." The study pointed out that only 11.3 percent of the estimated total consumption of 27 million tons of paper and paperboard comes from local production. Only 1 wood-pulp mill and 7 paper mills are now operating in the 9-State area. The combined output of the 8 mills is about 200,000 tons of paper.

Water quality important factor in pulp and paper manufacture

The quantity and availability of water is primarily regarded as one of the key items when considering pulp and paper mill location. Water quality, however, is of equal importance. Unless the water meets certain minimum standards it is of little value.

The Technical Association of the American Pulp and Paper Industry has established minimum standards of water quality for various grades and types of pulp and paper. These standards are shown in the following table.

Type of paper	Turbidity	Color	Total Hardness	Iron	Manganese	Total dissolved solids
			parts per million			
Groundwood	50	30	200	0.3	0.1	500
Unbleached Kraft	100	100	200	1.0	0.5	500
Bleached Kraft	40	25	100	0.2	0.1	300
Soda and sulfate	25	5	50	0.1	0.05	250
High grade light colored	10	5	100	0.1	0.05	200

A study was made to determine how many of the sites proposed for pulp- and paper-mill location in the Central Rocky Mountains meet the water-quality requirements as set forth. The results, which are being processed for publication, show that few of the locations qualify without some additional water processing. Water can be modified through processing, but it is costly and therefore limited in application.

House-log firm starts operation in Arizona

Production of a specially machined house log began in a plant near Prescott, Arizona. The product consists of a turned log 8 feet long and between 7 and 9 inches in diameter. A 3-inch hole is drilled the entire length of the log and a tongue and groove is provided on each piece. The purpose of the hole is to accelerate seasoning, retard checking, reduce weight, and improve insulation. The firm provides the building plans for the homes, which are designed on the basis of 8-foot length material. Because of the relative short length, considerable crook can be tolerated in the trees. Frequency and size of knots likewise are not critical. Heartrot that does not extend outside the 3-inch hole is acceptable.

Beet- and wood-sugar production cannot be integrated

A study was made to determine whether beet sugar and wood sugar could be produced in the same plant. An integrated production would greatly extend the operating period of the plant and help stabilize employment. However, it was found that the two processes could not be integrated advantageously. The modification required in the beet plant to safeguard against corrosion by the acidic wood-sugar solution would cancel any savings. Moreover, it would probably be impossible to remove all trace of wood odor before returning to beet-sugar production.

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RANGE MANAGEMENT RESEARCH

Three new phases of range management research were initiated in 1955. They are: (1) Research on the effects of pocket gophers on rangelands, (2) research on management of range used by big game and livestock in the Black Hills, and (3) research in the management of alpine and subalpine sheep ranges.

The effects of pocket gophers on rangelands

A cooperative research program entered into by the Colorado Agricultural Experiment Station, the U. S. Fish and Wildlife Service, and the Forest Service was organized in 1955, with the assistance of the Colorado Cattlemen's Association. The program has four major objectives:

1. To develop effective, practical methods and techniques for controlling pocket gophers under field conditions;
2. To understand the biology of the pocket gopher with special reference to those factors that influence the rise and fall of populations;
3. To determine the effect of pocket gophers on range vegetation, soils, and watershed values, and to determine the effects on gopher populations of manipulating range vegetation; and
4. To determine conditions under which pocket-gopher control is needed or would be economical.

The Forest Service, assisted by the Colorado Agricultural Experiment Station, is conducting the studies under objective 3. This aspect of the cooperative study under different grazing intensities was begun on Black Mesa, Gunnison National Forest.

Range research in the Black Hills

It is anticipated that the scope of the program will include research on the improvement and management of ranges used by both big game and livestock. Cattle and sheep graze Black Hills ranges during the summer, and mule and white-tailed deer graze them yearlong. Sharp differences of opinion exist concerning the competitive relationships between livestock and deer. Through the years, Kentucky bluegrass (Poa pratensis) has become established in the alluvial soils in many of the drainages, accompanied by a decrease in the

brushy species such as willow (Salix spp.), chokecherry (Prunus virginiana demissa), and dogwood (Cornus spp.), important deer forages. What conditions are desired from the viewpoints of livestock production, deer production, and streamflow, and how to bring about the most desirable conditions are problems needing study.

Research on management of alpine-subalpine sheep ranges

Alpine and subalpine ranges represent a main source of summer forage for the sheep industry of Colorado, Wyoming, and northern New Mexico. They also are the origin of many of the major streams of the region and are, therefore, of great importance to the population centers at the lower elevations.

Initial research, begun in 1955, was an inventory of vegetation conditions and of management practices and problems encountered in grazing sheep on these high-elevation ranges. Sixteen sheep allotments, representative of vegetation and range conditions encompassed, were studied.

On the basis of range, abundance, amount of herbage produced, and use by sheep, the following plants and groups of plants are the most important:

Tufted hairgrass	Deschampsia caespitosa
Alpine timothy	Phleum alpinum
Bluegrasses	Poa spp.
Spiked trisetum	Trisetum spicatum
Sedges	Carex spp.
Kobresia	Kobresia bellardi
Rushes	Juncus spp.
Clovers	Trifolium spp.
Marshmarigold	Caltha leptosepala
Oreoxis	Oreoxis alpina
Groundsel	Senecio spp.
Fleabane	Erigeron spp.
Willows	Salix spp.

In general, alpine and subalpine ranges were found to have a good ground cover. The ground-cover indices ranged from 100 to 33 percent. Ninety percent of the sites had ground-cover indices of 60 percent or higher and 72 percent had ground-cover indices of 70 percent or higher. Herbage production of all species varied greatly from 121 pounds per acre on some sites to 1,346 pounds per acre on others. "Meadow sites" (the more moist areas in the swales) produced 258 to 1,346 pounds per acre; whereas the "turf sites" (the well-drained slopes and ridgetops) produced 121 to 730 pounds per acre of all vegetation. The range in herbage production of

plants grazed by sheep was 156 to 1,146 pounds per acre on the meadow type and 37 to 581 pounds per acre on the turf type. This production is as high as will be found on most lower elevation ranges.

Technical bulletin on mesquite invasion is published

U. S. Department of Agriculture Technical Bulletin No. 1127 entitled "Reproduction and Establishment of Velvet Mesquite as Related to Invasion of Semidesert Grasslands," by George E. Glendening and Harold A. Paulsen, Jr., brings together information on factors important in the spread of mesquite (Prosopis juliflora var. velutina) from studies in southern Arizona.

Characteristics of velvet mesquite that adapt it for invasion in semidesert grasslands include (1) the production of an abundance of seeds that remain viable for several years; (2) the ability of seeds to germinate and grow under a wide range of temperature and moisture conditions; and (3) the capacity of the plants to sprout following injury to the top growth. Livestock are important in the spread of mesquite seeds because they consume considerable quantities of seed pods even when considerable grazing is available. Cattle commonly travel 1 to 3 miles daily and spread mesquite seeds over a wide area. Kangaroo and wood rats, commonly found on mesquite sites, collect and store the seeds. Although rodents do not transport the seeds as far as livestock, they contribute to the thickening of the stand. Runoff water is another agent that disseminates mesquite seeds.

Competition by some of the better forage grasses such as bush muhly (Muhlenbergia porteri), Arizona cottontop (Trichachne californica), and black grama (Bouteloua eriopoda), retards the establishment of seedlings. Therefore, grazing practices that will allow maximum development of grasses are desirable. When mesquite becomes established, the grass cover declines and brush continues to increase unless artificially controlled.

In experiments with control burning, 52 percent of mesquites less than one-half inch in stem diameter were killed by fire during tests in late spring. However, in these tests only 8 to 15 percent of the trees larger than one-half inch stem diameter were killed.

Most southwestern chaparral shrubs sprout following burning

Four of the six most common species of chaparral shrubs on the Sierra Ancha Experimental Forest in central Arizona sprout following burning. Clumps of six shrub species were burned with a gasoline torch. Half of the plots are being burned annually and the others at 2-year intervals. Number of sprouts at varying intervals following burning give some indication of the inherent resistance of the several species to fire and of their susceptibility

to effective control by repeated burning. The following tabulation compares numbers of sprouts by species developing 1 year and 2 years after burning. The compilation also shows the effect of a repeat burn 1 year after the initial burn.

Species	Number of live stems or sprouts at ground level		
	Before burn of July 1953	Before burn of June 1954	June 1955
Desert ceanothus (*Ceanothus greggi*)			
Burned annually	173	0	1
Burned at 2-year intervals	223	Not burned	22
Hollyleaf buckthorn (*Rhamnus crocea ilicifolia*)			
Burned annually	21	62	0
Burned at 2-year intervals	33	Not burned	183
Skunkbush sumac (*Rhus trilobata*)			
Burned annually	91	26	0
Burned at 2-year intervals	95	Not burned	529
Pointleaf manzanita (*Arctostaphylos pungens*)			
Burned annually	58	0	0
Burned at 2-year intervals	51	Not burned	0
Shrub live oak (*Quercus turbinella*)			
Burned annually	241	1,419	759
Burned at 2-year intervals	303	Not burned	2,463
Wrights silktassel (*Garrya wrighti*)			
Burned annually	15	7	26
Burned at 2-year intervals	25	Not burned	58

Based on the foregoing data, the following conclusions can be drawn:

1. Pointleaf manzanita is a nonsprouter; it can be killed with one burn.
2. Amount and vigor of sprouting varies with species. Wrights silktassel is a weak sprouter, and shrub live oak is the strongest sprouter of the group.
3. Desert ceanothus, skunkbush sumac, and hollyleaf buckthorn were essentially eliminated by burning in two successive years.

Burning is more effective for controlling burroweed than for cactus

An area on the Santa Rita Experimental Range in southern Arizona supporting 600 pounds of herbage per acre was burned in June 1952 to determine the effectiveness of fire for killing burroweed, cactus, and mesquite. Plant kills, as previously reported, were: burroweed (*Aplopappus tenuisectus*) -- 88 percent; pricklypear

cactus (Opuntia engelmanni) -- 28 percent; staghorn or cane cholla (O. spinosior) -- 42 percent; jumping cholla (O. fulgida) -- 44 percent; and velvet mesquite -- 9 percent. Portions of the area were reburned in June 1955. Counts of the woody plants were made prior to the fire and again in the fall, following the burn, on the plots burned only in 1952 as well as on the reburned plots. It is too early to appraise the final effects of reburning on mesquite, but apparently there were no important effects. The 1955 fire killed 92 percent of the burroweed that was on the plots immediately prior to the burn. The once-burned plots showed a 6-percent increase in burroweed during the 1955 growing season.

The effectiveness of prescribed burning as a means of killing cholla cactus was at least partially nullified by the establishment of new plants from stem joints that break off and fall to the ground. Net loss or gain in numbers of plants were:

Species	Reburned plots, 1955 (pct.)	Burned plots, 1952 (pct.)
Cane cholla	+ 13	+ 47
Jumping cholla	+ 18	+104
Pricklypear	- 35	+ 13

Apparently the tendency to reproduce vegetatively is weaker in prickly-pear. Additional observations and studies will be necessary to adequately evaluate prescribed burning as a means of controlling unwanted range plants.

Aerial spraying of mesquite boosts forage production

The invasion of southern Arizona rangelands by mesquite is often so complete that the native perennial grasses are almost eliminated. On such ranges there is a question as to whether mesquite control is all that is needed to bring about range recovery or whether range reseeding is needed to speed the process. A partial answer to this question was obtained from a study on the Santa Rita Experimental Range. Mesquite was sprayed with 2,4,5-T by airplane in mid-May 1954, and seeded to Lehmann lovegrass (Eragrostis lehmanniana) by airplane at the same time. Observations on seedling establishment and herbage production of Lehmann lovegrass and of native perennial grasses were made in the falls of 1954 and 1955 on the sprayed area and on an adjacent unsprayed reseeded area. Moisture conditions were favorable in the summers of both 1954 and 1955. The average number of lovegrass seedlings per square-foot was as follows:

Year	Sprayed area (No. per sq.-ft.)	Unsprayed area (No. per sq.-ft.)
1954	0.41	0.16
1955	0.50	0.25

Thus, even with 2 years of high rainfall, many more lovegrass seedlings were established on the sprayed area than where the mesquite was not controlled. In years of average or below-average rainfall, the contrast in favor of controlling mesquite probably would be even greater.

Despite the increased number of plants, lovegrass made no measurable contribution to herbage yield on the unsprayed area even in 1955. On the sprayed plots, lovegrass yielded about 70 pounds of herbage per acre. This was about one-tenth of the total herbage production from perennial grasses. However, since lovegrass stays green later in the fall and greens up earlier in the spring than do most of the native grasses, it can be much more valuable than these production data indicate.

The tremendous response of native perennial grasses was more striking than the effects of mesquite control on the success of seeding. The density of perennial grasses prior to spraying was so low that reseeding was thought to be necessary. Still, herbage production from native perennial grasses (on the sprayed area) rose to 343 pounds in 1954 and on up to 668 in 1955. Yields on the unsprayed area for 1954 and 1955 were 130 and 113 pounds per acre, respectively. It is apparent that mesquite control, together with two good growing seasons, results in a great deal of grass even without seeding.

Different control methods desirable for different types of juniper stands

Observations have been made on pinyon-juniper control methods being used by Governmental agencies and stockmen while studying factors affecting conditions and production of woodland ranges. These emphasize the necessity of adopting methods suited to the type of stand and to the rancher's particular situation.

Cabling (dragging heavy cable between two large tractors) is one of the least expensive control methods, but it is effective only with large old trees that are stiff enough to uproot rather than bend over when the cable hits them. It is also best adapted to relatively smooth and rockfree areas. Costs average $1 to $1.50 per acre.

With scattered stands of young or mixed-age juniper, various types of bulldozing equipment can be used effectively and at costs varying from 4 to 13 cents per tree and averaging about 7 cents. The "Hulacat," which has a dozer blade that can be tilted to either side by hydraulic power, is especially efficient. Dozer control can be used on somewhat rougher, rockier ground than can cabling.

The control project on the Fort Apache Indian Reservation has largely been accomplished by chopping out the junipers with axes. Hand methods can be the most thorough of all. Costs may be reasonable in scattered stands of young trees, but are high in denser stands. On the Reservation costs were $5 to $7 per acre. Hand methods are justified here in part by the winter-season labor provided for the Indians.

Controlled burning promises to have some use in juniper control, but considerably more research is needed to define its limitations and to develop methods for fire use. Similarly, early tests of chemical sprays have not been promising, and further research is needed to develop satisfactory means of chemical control. Other methods of control are being tested and may prove of value in some types of stands.

Removing pinyon and juniper gives increased herbage yields

Pinyon and juniper control was tested on a small scale on the Fort Apache Indian Reservation as early as 1941, and a major control project was started in 1946. By the end of 1954, approximately 80,000 acres had been controlled, and the project was continuing at a rate of about 20,000 acres per year. Thus the Reservation provides an excellent area for studying changes in forage production that result from removing the trees.

Herbage production of perennial grasses and forbs was measured in the fall of 1953 on areas from which juniper had been removed in different years, and which had been protected or only winter grazed since control. By analysis of herbage yields in relation to years since juniper control, the rate of herbage recovery can be estimated. As shown in figure R-1, recovery is rapid at first and tapers off after 7 or 8 years. Full production of 650 to 700 pounds per acre (air-dry) would be reached about 10 years after control. These results were obtained on areas that were ungrazed, or grazed only in the winter. Summer-grazed or yearlong-grazed areas did not recover so rapidly.

Changes in grazing capacity related to shrub type on the Jornada Experimental Range

Analysis of 38 years of records on six range pastures on the Jornada Experimental Range in southern New Mexico shows that changes in grazing capacity over the years have been greatest on the ranges containing the highest proportion of shrub type and least on grassland ranges. The acreage and type composition of the six pastures, totaling approximately 140,000 acres, are as follows:

	Pasture No.					
	1	2	5	6	9	10
Surface acres	83,961	29,512	1,780	14,658	3,172	7,172
	- - - - - - - - percent - - - - - - - -					
Plant types						
Grasslands:						
Black grama	4.6	23.7	78.6	12.3	89.2	80.6
Tobosa	5.0	3.0	0	1.6	0	0.7
Grama & mixed grass	5.1	7.8	3.5	0.4	6.2	3.0
Tobosa & mixed grass	3.6	0.3	7.4	26.0	0	14.8
Brush types:						
Mesquite	46.4	65.2	10.5	1.7	4.6	0.3
Tarbush-creosotebush	35.3	0	0	58.0	0	0.6

The pastures fall logically into two groups. Three pastures (1, 2, and 6) contain a relatively large proportion of brush types, but the others (pastures 5, 9, and 10) are predominantly grasslands. The average grazing capacities of the grassland pastures have changed but little from 1916 through 1953, even though large year-to-year variations resulted from variations in weather (fig. R-2). If the recent drought years were omitted, even the slight reductions in grazing capacity, which are indicated by an increased surface acreage requirement per animal unit, would be virtually eliminated for pastures 9 and 10. Ten percent of pasture 5 was occupied by the mesquite type. This undoubtedly is the cause of the reduction in capacity of that pasture.

In contrast, the average grazing capacities of pastures 1, 2, and 6 decreased markedly during the same period. Pasture 2, which shows an increasingly rapid rate of decline in grazing capacity, had 65 percent of its area covered by mesquite.

The average surface-acre requirement of the grassland range on the Jornada Experimental Range over the 38-year period was 80 surface acres per animal unit (one cow for a year), or 8 animal units per section. In contrast, the average surface-acre requirement on ranges having 60 percent or more in brush was 146 surface acres per animal unit, or 4.4 animal units per section.

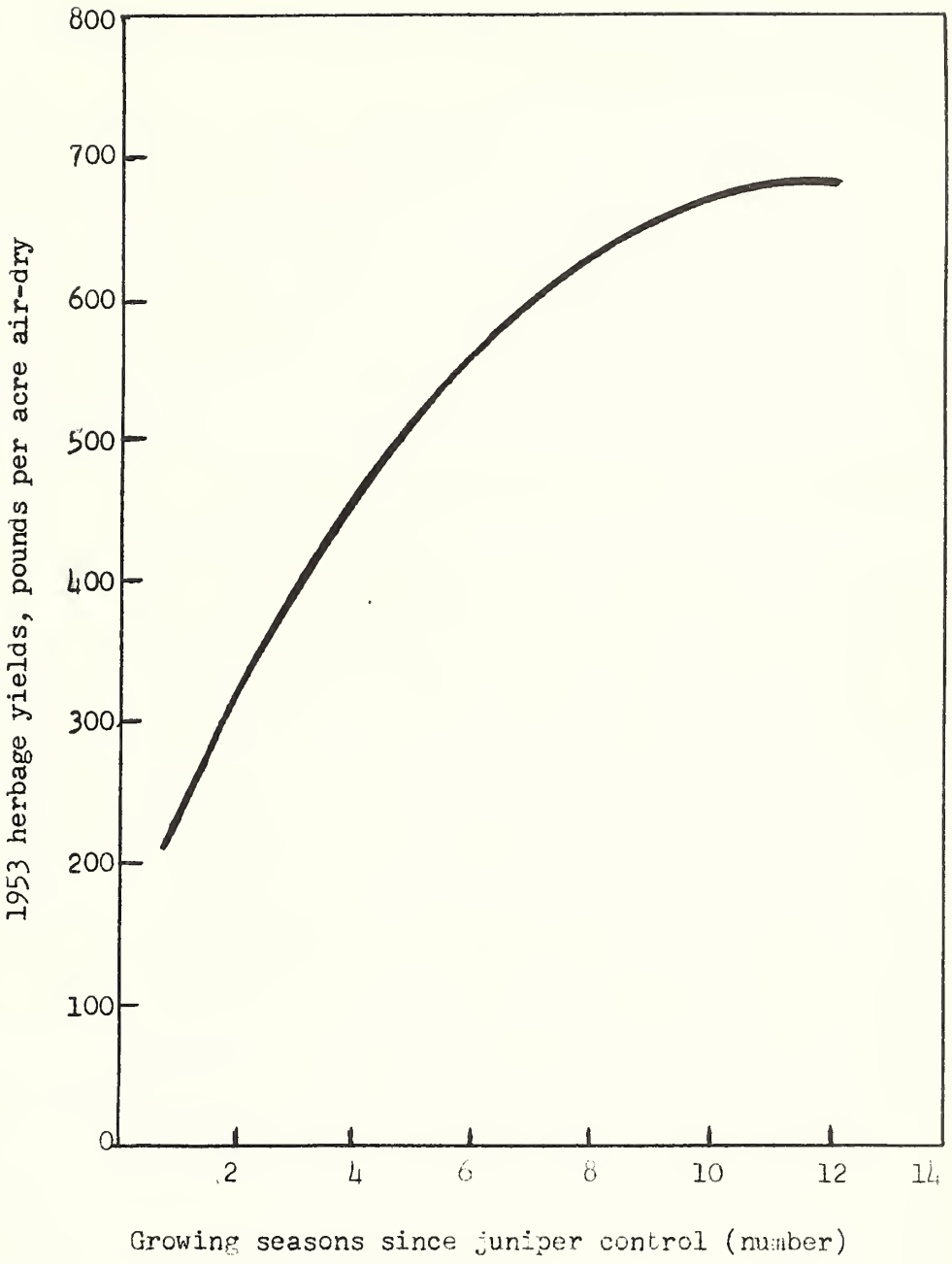
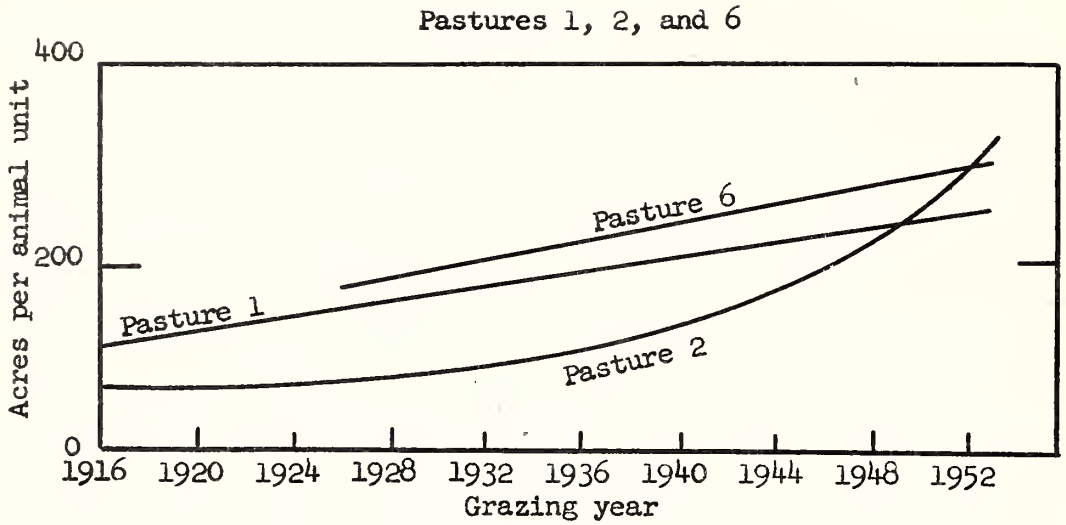


Figure R-1.--Yield of herbage of perennial grasses and forbs in 1953 in relation to growing seasons since juniper control. Areas protected or limited to winter grazing.



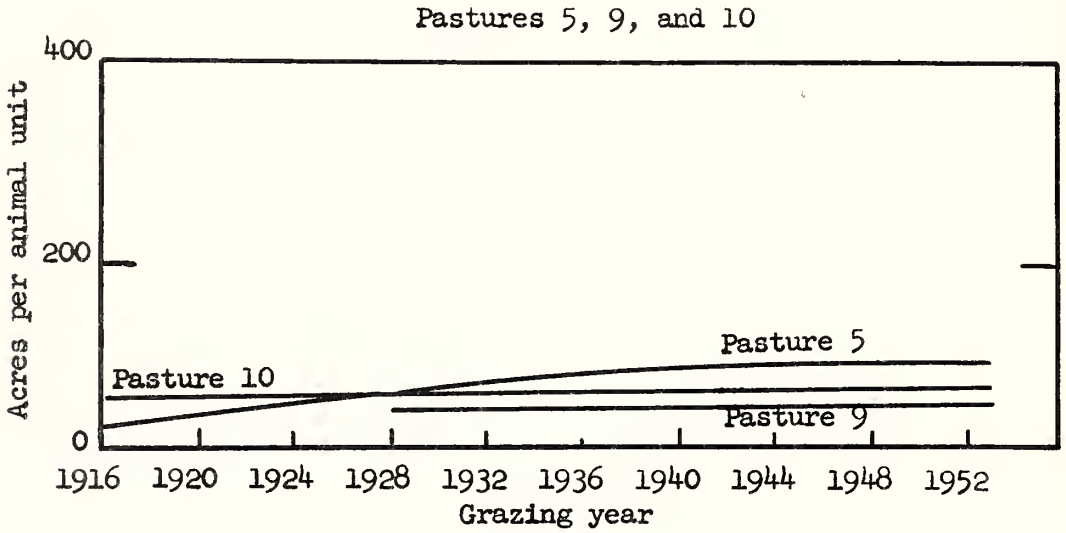


Figure R-2.-- Surface acre requirements per animal unit on six experimental pastures, Jornada Experimental Range, 1916-1953, inclusive.

Yearling cattle gain more in the spring than in the fall on crested wheatgrass in northern New Mexico

Yearling heifers and steers on seeded crested wheatgrass (Agropyron cristatum) range near Tres Piedras, New Mexico, gained an average of 2.0 pounds daily for 34 days in the spring of 1955. The average daily gain of the same animals when placed on adjacent crested wheatgrass range in the fall was 1.4 pounds per day per animal. The fall grazing was from October 7 to 31 after summer grazing on the higher lying national forest range.

Daily gains of yearling steers and heifers on crested wheatgrass range of the Laguna Seca Allotment, Santa Fe National Forest, (Elbert K. Collins ranch), averaged higher in the spring than in the fall. Results of weighing cattle in 2 years are as follows:

Year	Grazing period	Yearling heifers (Lb. per day)	Yearling steers (Lb. per day)
1954	May 5 to June 3	2.8	2.9
	September 8 to November 5	1.1	-
1955	May 5 to June 11	2.1	2.1
	September 7 to November 2	1.3	1.5

These results are in agreement with previous findings. In the spring of 1954, yearling gains averaged 2.8 pounds daily on the Tres Piedras area. In 1949 and 1950, yearlings gained an average of 1.7 pounds daily on fall-grazed experimental crested wheatgrass pastures on Glorieta Mesa, Santa Fe National Forest.

Nutritive value of crested wheatgrass highest in the spring

Results obtained in the cooperative study with New Mexico Agricultural Experiment Station, on crested wheatgrass show the reason for better weight gains in the spring.

Samples clipped at different times during the year from the Laguna Seca Allotment (Elbert K. Collins ranch) illustrate the progressive declines in crude protein and increases in crude fiber content of crested wheatgrass as the season progresses. Green leaves sampled October 28, which had developed at the base of the plants, contained 22.3 percent crude protein and only 15.7 percent crude fiber. This indicates a high nutritional value for fall regrowth.

Date of clipping	Growth stage	Crude protein (pct.)	Crude fiber (pct.)
May 7	Immature	19.8	19.8
June 25	Mature	8.2	30.8
July 27	Mature	7.4	30.0
September 3	Mature	6.7	28.9
October 28	Mature	6.9	31.2
November 1	Mature	5.2	33.4

Nutritive value of mature crested wheatgrass compares favorably with blue grama

Cooperative studies also show that the nutritive value of crested wheatgrass is remarkably high in the spring when plants are green and succulent. Even when mature, crested wheatgrass compares favorably with mature blue grama (Bouteloua gracilis). Nutrition experiments conducted at State College, New Mexico, by W. E. Watkins, using wethers as test animals, showed the following values:

	Crested wheatgrass		Blue grama	
	Very immature	Mature & weathered	Near maturity	Slightly weathered
	- - - - - - percent - - - - - -			
Crude protein:				
Chemical composition	19.8	5.2	6.0	4.2
Digestion coefficients	84.8	45.7	46.2	28.5
Crude fiber:				
Chemical composition	19.8	33.4	34.2	34.9
Digestion coefficients	79.3	58.6	55.4	51.0
N-free extract:				
Chemical composition	41.9	46.6	44.6	44.7
Digestion coefficients	81.5	51.8	47.1	44.4
Total digestible nutrients	71.1	48.2	43.8	39.4

When in the immature stage during the early spring grazing season, 100 pounds of air-dry crested wheatgrass forage contains 16.8 pounds of digestible protein. At maturity and when slightly weathered, as it is during the fall grazing season, crested wheatgrass contains a higher percentage of digestible nutrients than blue grama at a comparable growth stage.

Crested wheatgrass production holds up at Cebolla Mesa under all grazing intensities tested

Herbage yields on the 3 experimental spring-grazed crested wheatgrass pastures varied from 190 to 791 pounds per acre.

Grazing at the 3 rates has shown no real differences in herbage production. Apparently, the heaviest utilization of crested wheatgrass, which averaged about 70 percent during the short spring grazing season that never exceeded 34 days, has not yet adversely affected herbage production. Instead, this pasture has increased proportionately more in yield than the two less intensively grazed pastures.

	Herbage yields			
	1952	1953	1954	1955
	(Lb. per acre, air-dry)			
Pasture 1 (heavily grazed)	189	251	551	515
Pasture 2 (moderately grazed)	212	309	616	481
Pasture 3 (lightly grazed)	336	460	791	606

Spring forage produced by crested wheatgrass related to fall-winter-spring precipitation

Herbage yield at Cebolla Mesa (30 miles north of Taos, New Mexico) shows some relation to September 1 to May 31 precipitation as given in figure R-3. Production measured in June when crested wheatgrass plants are nearing maturity is more closely related to the 9-month antecedent precipitation than to any other period of antecedent precipitation. Yield figures were not obtained in 1951. However, as shown in figure R-3, a drop in herbage production accompanied a drop in the precipitation during the preceding period from September 1 to May 31, and likewise herbage production increased with increased precipitation. The relationship was particularly close from 1952 to 1955, inclusive. During the entire period of study, starting 2 years after planting of crested wheatgrass, precipitation was below average; yet, in spite of this low precipitation, herbage production has been appreciable.

Best time for seeding wheatgrasses in north-central New Mexico is in the fall

Studies conducted on the Elbert K. Collins ranch during 1951 to 1954 indicated generally better success from seeding in the fall than in spring or summer. Plantings were made at weekly intervals in May, June, September, and October, and twice weekly in July and

August each year. Seedling counts were taken twice a year to determine initial establishment and survival.

Time of planting	Expectancy of stand establishment
May and June	Poor risk
July and August	Fair to good stand - 80 percent of the time
September and October	Good stand - 90 percent of the time

The success of September and October seedings appeared to be largely the result of abundant precipitation, mostly snow, during the November to May period. July and August seedings gave poorer results, probably because of infrequent rains and moisture deficiency. Summer precipitation for the 3 years of planting averaged 32 percent less than the 26-year average. Seedings made in May and June resulted in the lowest average plant establishment.

May and June seedings should be avoided. Within the drier portions of the ponderosa pine (Pinus ponderosa) zone and the wetter portions of the pinyon-juniper woodland zones, planting should commence in summer after about 0.4 inch of rain has fallen during a 3-day period.

Range seeding handbook for southwestern ranges published

U. S. Department of Agriculture Handbook No. 89 entitled, "Seeding in the Southwestern Pine Zone for Forage Improvement and Soil Protection," by Fred Lavin and H. W. Springfield, summarizes available information on how to seed rundown ranges and timberlands disturbed by fire, logging, and construction in the ponderosa pine zone of Arizona and New Mexico. Twenty-three promising species of grasses are discussed to indicate where they have promise in the Southwest. Although, as in many other range sections, crested wheatgrass and intermediate wheatgrass (Agropyron intermedium) show the widest range in adaptability, smooth brome (Bromus inermis), orchardgrass (Dactylis glomerata), tall wheatgrass (A. elongatum), and several other species have their place. On burns and other disturbed areas, for example, species most easily established are intermediate, tall, and slender (A. pauciflorum) wheatgrasses, orchardgrass, blue wildrye (Elymus glaucus), and Canada wildrye (E. canadensis). Where annuals are desired for immediate soil protection, black mustard (Brassica nigra) and India mustard B. juncea) are recommended.

Methods of site preparation, seed distribution and coverage, seeding rates, time of seeding, costs, and method of handling seeded grass stands best adapted to conditions in the pine zone are discussed.

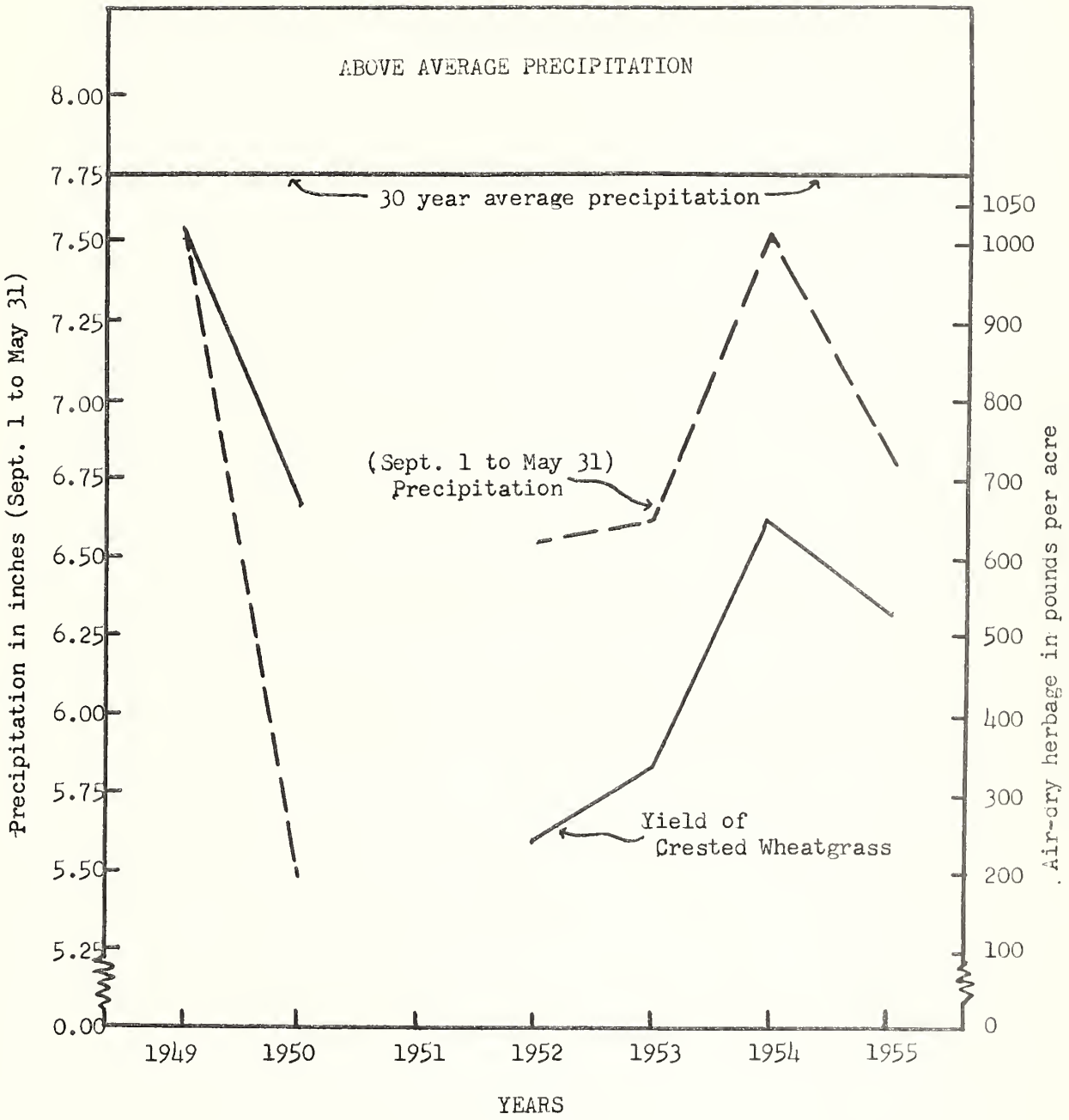


Figure R-3.--Relation of seasonal precipitation to herbage yields of crested wheatgrass seeded on Cebolla Mesa in 1947. Grazing was at an average intensity of about 50 percent utilization by weight. No data were available for 1951.

Cooperative range-watershed study being undertaken

A study in ccoperation with the Bureau of Land Management, Geological Survey, and the Forest Service is being undertaken near the community of San Luis in the Rio Puerco drainage of northern New Mexico. Effects of winter cattle grazing at two intensities and the use of land treatment in combination with light grazing, on soil erosion and water runoff and vegetation are being evaluated on three experimental watersheds. Preliminary studies in the area show that galleta (Hilaria jamesi), blue grama, and alkali sacaton (Sporobolus airoides) are the main forage species. Other species that make up important amounts of forage are sand dropseed (Sporobolus cryptandrus), threeawns (Aristida spp.), big sagebrush (Artemisia tridentata), shadscale (Atriplex curtipendula), and chamiza (Atriplex canescens). Cattle are grazed during a 6-month winter season. Under these conditions alkali sacaton is the most heavily grazed and blue grama the least heavily grazed. Galleta and sand dropseed are used in intermediate amounts. Of the shrubs, chamiza is the most palatable, shadscale intermediate in palatability, and the sagebrush was used only lightly. Utilization of the several species varies somewhat with the types in which they occurred, whether in the alluvial bottoms, on the slopes or uplands, or in the sagebrush or pinyon-juniper types.

The following table shows the average use of the species in each main vegetation type:

Species	Average utilization by weight by subtypes			
	Alluvial grassland	Upland grassland	Sagebrush-grass	Pinyon-juniper
	- - - - - - - percent - - - - - - -			
Galleta	33	20	8	17
Alkali sacaton	56	40	30	34
Blue grama	9	8	2	2
Sand dropseed	10	12	10	20
Threeawn	--	5	--	--
Shadscale	43	18	--	15
Big sagebrush	8	0	1	--
Chamiza	--	72	--	--

Russian wildrye produces excellent forage in ponderosa pine type in Colorado

Russian wildrye (Elymus junceus) at the Manitou Experimental Range in Colorado produces exceptional crops of forage even under adverse conditions. During 1955 it exceeded all other single species

being tested for range reseeding in both grazing capacity and in cattle gains. Only the mixture pastures consisting of crested wheatgrass, smooth brome, and, originally, yellow sweetclover (Melilotus officinalis) outproduced the Russian wildrye.

The ability of Russian wildrye to make new growth on small amounts of moisture is responsible for the greater grazing capacity and gains of livestock. Results are shown in comparison with other grasses in the following tabulation:

Species	Herbage yield 3/ (pounds)	Heifer days of grazing per acre 3/ (days)	Weight gains per acre on heifers (pounds)
Russian wildrye	840	39.9	82.0
Intermediate wheatgrass	936	33.8	64.4
Crested wheatgrass	827	28.5	64.5
Smooth brome	548	19.5	38.5
Mixture (crested wheatgrass, smooth brome, and yellow sweetclover)	1,179	44.9	86.3

Oak brush in west-central Colorado shows little evidence of recent spread

Oak brush is often a subject of controversy, especially in western Colorado where it occupies more than 1 million acres. Some people contend that it has spread or thickened greatly during recent years, thereby reducing the acreage of usable rangeland and causing a decline in water yields. Others point out the value of oak brush as watershed cover in preventing soil erosion. Game managers generally look with favor upon the brush as providing food and shelter for wild animals. To learn more about the characteristics of the oak brush type in west-central Colorado, a detailed study of 41 sites was made in 1953 and 1954.

About one-third of the oak stands examined were found to be dense thickets, which are relatively inaccessible to livestock. The majority of the stands, however, are more open with the oak often growing in scattered clumps. Grazing use of such areas appears to be nearly as great as in the openings. Oak stands in some areas have thickened in recent years chiefly as a result of fire, but a study of annual rings shows that the general extent of the type has changed relatively little during the past 75 years.

A comparison of average soil and plant cover in the oak and adjacent openings is given in the following tabulation.

3/ Based on moderately stocked ranges.

	Oak	Openings
Bare soil (percent)	4	29
Soil stability rating (Parker method)	Excellent	Fair
Depth of surface soil (inches)	17	20
Sedge production (pounds per acre)	202	25
Grass production (pounds per acre)	118	339

No site factor was obviously limiting the spread of brush into the openings. Depth of surface soil was nearly the same, and there was little difference in other characteristics observed. Effectiveness of oak brush in preventing erosion is obvious in that only 4 percent of the ground surface is exposed. On three-quarters of the open sites erosion was judged to be moderate to severe. Perhaps the greatest difference is in the kind of plant cover. Elk sedge (Carex geyeri) is predominant under oak, while Kentucky bluegrass grows mainly in the openings. Total production of grasses and sedges is nearly the same under both conditions.

Idaho fescue is the most important grass on Bighorn ranges

Previous studies on cattle ranges in the Bighorn National Forest of Wyoming have shown that Idaho fescue (Festuca idahoensis) is the most abundant species of grass, produces the most herbage, has the highest preference for cattle grazing, and contributes most to the forage intake of the cattle. The species is also of high nutritional value. Analysis made in 1954 shows that Idaho fescue is superior to other grasses in forage quality.

Idaho fescue had a higher percentage of crude protein during all stages of development than slender wheatgrass, pumpelly brome (Bromus pumpellianus), big bluegrass (Poa ampla), or subalpine needlegrass (Stipa columbiana). In the early stage (seed heads showing), differences among the grasses were not great; they ranged from 10.5 percent to 13.12 percent. However, as growth developed, the crude protein content of Idaho fescue stayed higher than the other species. Crude protein content of all plants was lowest when the plants were dry. At that stage the protein content of Idaho fescue was 6.75 percent compared with 4.38 percent for big bluegrass, the next highest, and 2.81 percent for slender wheatgrass, the lowest.

Comparative values of crude protein for some associated grasses on the Bighorn National Forest, 1954, are shown below.

	Stage of development				Average of samples
	Heads showing	Blooming	Seed ripe	Plant dry	
Approximate date	July 15	July 28	Aug.25	Sept.22	
	- - - percent crude protein - - -				
Species					
Idaho fescue	13.12	10.75	8.81	6.75	9.85
Big bluegrass	12.03	9.19	6.69	4.38	8.07
Pumpelly brome	12.56	9.50	5.56	3.44	7.77
Slender wheatgrass	12.94	8.56	5.25	2.81	7.39
Subalpine needlegrass	10.50	7.81	4.31	2.94	6.39

An interesting comparison may be made between the preference rating of these 5 grasses and their nutritional value as reflected by the content of crude protein. Previous studies of preference use by cattle rate these 5 species in descending order of preference as Idaho fescue, big bluegrass, pumpelly brome, slender wheatgrass, and subalpine needlegrass. The average crude protein content for the season would rank the species in exactly the same order from the standpoint of nutritional value.

Vigor of Idaho fescue is related to the intensity of grazing received

Measurements made in 1955 show that leaf heights, basal area, and total weight per plant of Idaho fescue vary considerably by grazing intensity and soil type on the experimental pastures on the Bighorn National Forest. The pastures have been grazed for 5 years at intensities of 75, 50, and less than 25 percent of the height growth removed. Differences between the degrees of grazing as reflected by these measurements are shown in the following tabulation.

	Pasture No.		
	1	2	3
Average degree of herbage removal (percent)	75	25	50
Sedimentary soil:			
Leaf height (inches)	6.3	9.6	7.9
Basal area (sq.-cm.)	4.0	7.8	6.5
Weight (grams per 10 plants)	15.1	21.0	16.9
Granitic soil:			
Leaf height (inches)	3.4	5.3	4.5
Basal area (sq.-cm.)	3.4	6.4	5.5
Weight (grams per 10 plants)	6.4	10.4	9.0

Growth of Idaho fescue during the season

Forty plants of Idaho fescue were clipped and weighed (air-dry) every 2 weeks during the growing season at each of 6 plant-development stations on the Bighorn National Forest for 4 consecutive years, 1952-55. These plant-development stations ranged from 7,200 to 9,500 feet in elevation. Production at any one date varied with elevation. However, when observations and clippings began at the time vigorous growth was well started, approximately the same number of days were required for Idaho fescue to reach maximum production at all of the stations. Plants reached their peak of herbage production in approximately 70 to 75 days, then weight of the herbage diminished rapidly. The general rate in development of Idaho fescue herbage and subsequent weight loss are shown in figure R-4

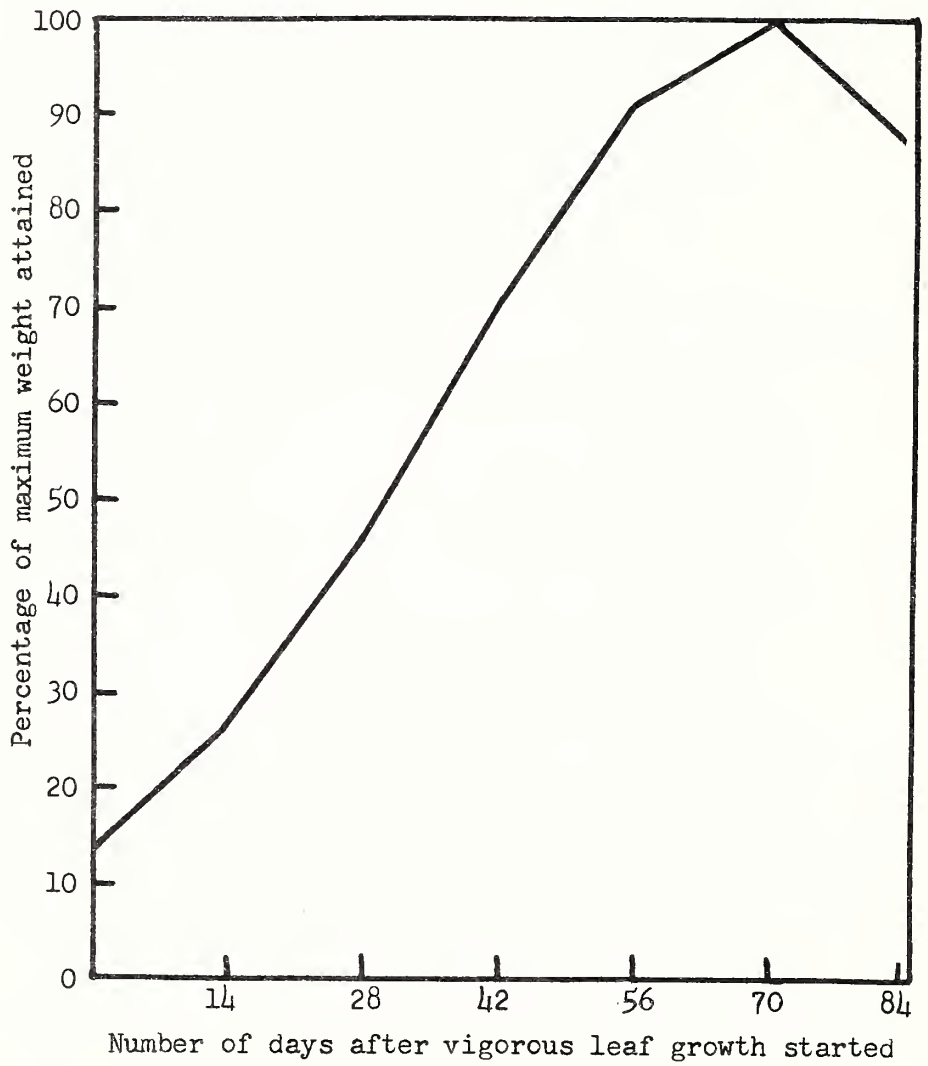


Figure R-4.—Herbage weight production of Idaho fescue during the growing season

WATERSHED MANAGEMENT RESEARCH

Watershed management research deals with the influences of forest and range vegetation upon water, soil, and climate. Water receives particular emphasis in the Rocky Mountain region where agriculture, industries, and cities are dependent on the streams arising in the mountains. During 1955, it was possible to strengthen going research projects and to begin some new studies. Interesting and important new research was started on phreatophytes in Arizona. Phreatophytes are plants such as salt-cedar, baccharis, and willows, which grow alongside streams and in wet areas. These plants use large quantities of water but are of little or no economic value. From our work, we expect to find replacement vegetation that will use less water and perhaps will yield useful products. New research was started in the Black Hills to provide information for watershed management in that area.

Alpine snowfields boost late summer streamflow

Measurement of total water content of 5 snowfields during the summer of 1955 reveals that the average melt released 1.5 acre-feet of water per acre of snow surface each week. Study sites were above 11,000 feet on the east slope of the Front Range between Mount Evans and the Trail Ridge road in Colorado. Observations began in July and lasted until mid-September. Recording instruments were used to keep track of temperature, humidity, wind, and precipitation. Weekly measurements of area, depth, and density of snow made possible an estimate of the total water stored in the field.

The rate of change in snow depth was a maximum of three-quarters of an inch per hour at mid-day on southerly exposures and a minimum of one-thirty-second of an inch per hour on north slopes during the night. The change in depth from week to week ranged from 1.1 to 3.3 feet and averaged about 2 feet.

Snow density was above 60 percent at the beginning of the season and exceeded 75 percent after August 1 as a result of rainfall and accumulated melt water. Density was remarkably uniform over the fields and at all depths.

This work was carried out in cooperation with the College of Forestry, State University of New York. Its purpose is to determine the importance of alpine snowfields in contributing to late summer streamflow. Aerial photographs are being used to obtain an estimate of the number, area, and exposure to the sun of snowfields in the Front Range. This will make it possible to apply the detailed findings of the survey to a larger area.

Fifty percent of year's streamflow leaves Fraser area in June

June is the big month for streamflow for watersheds above 9,500 feet elevation in northern Colorado. Fifteen years of stream gaging at the Fraser Experimental Forest near Fraser, Colorado show that, on the average, 50 percent of the waterflow for the year runs off in that 30-day period. In the 92 days from May 1 to July 31, 77 percent of the annual yield flows over the measuring gage. Figure W-2 gives the percent of total flow by months throughout the year. These values are for the Fool Creek watershed of 710 acres between 9,500 to 11,500 feet elevation. The concentration of flow indicates the importance of snowmelt to streamflow from the high mountain areas in the Central Rockies. Two-thirds of the year's precipitation falls as snow and this two-thirds is responsible for 90 percent of the year's streamflow.

Sediment movement has been nil during low streamflow years

Even though logging crews were busy on the Fool Creek watershed near Fraser, Colorado in 1954 and 1955, the stream has moved too little bed load to be measured in the trap basin below the Fool Creek stream gage. The high streamflow during 1952, which followed 3 years of road building on the watershed, moved off 105 tons of sand, gravel, and rock. High flows of the future will move whatever material was made unstable by the present logging job and indicate the effect of timber harvesting on bed load moved by the stream.

Figure W-1.-- One of four alpine snowfields where summer snow conditions were studied. The worker is getting a snow core which will be emptied into the bucket and weighed to determine density. Five of the stakes used to measure melt can be seen. Paint marks on the stake in the foreground permit depth of snow to be read at a glance. When this stake was first installed a month earlier, only the very top extended above the snow. Weather instruments were housed in the shelter on the skyline. Other snowfields can be seen in the background. On snow as steep as this, workers needed crampons and skill to stick on the slope.

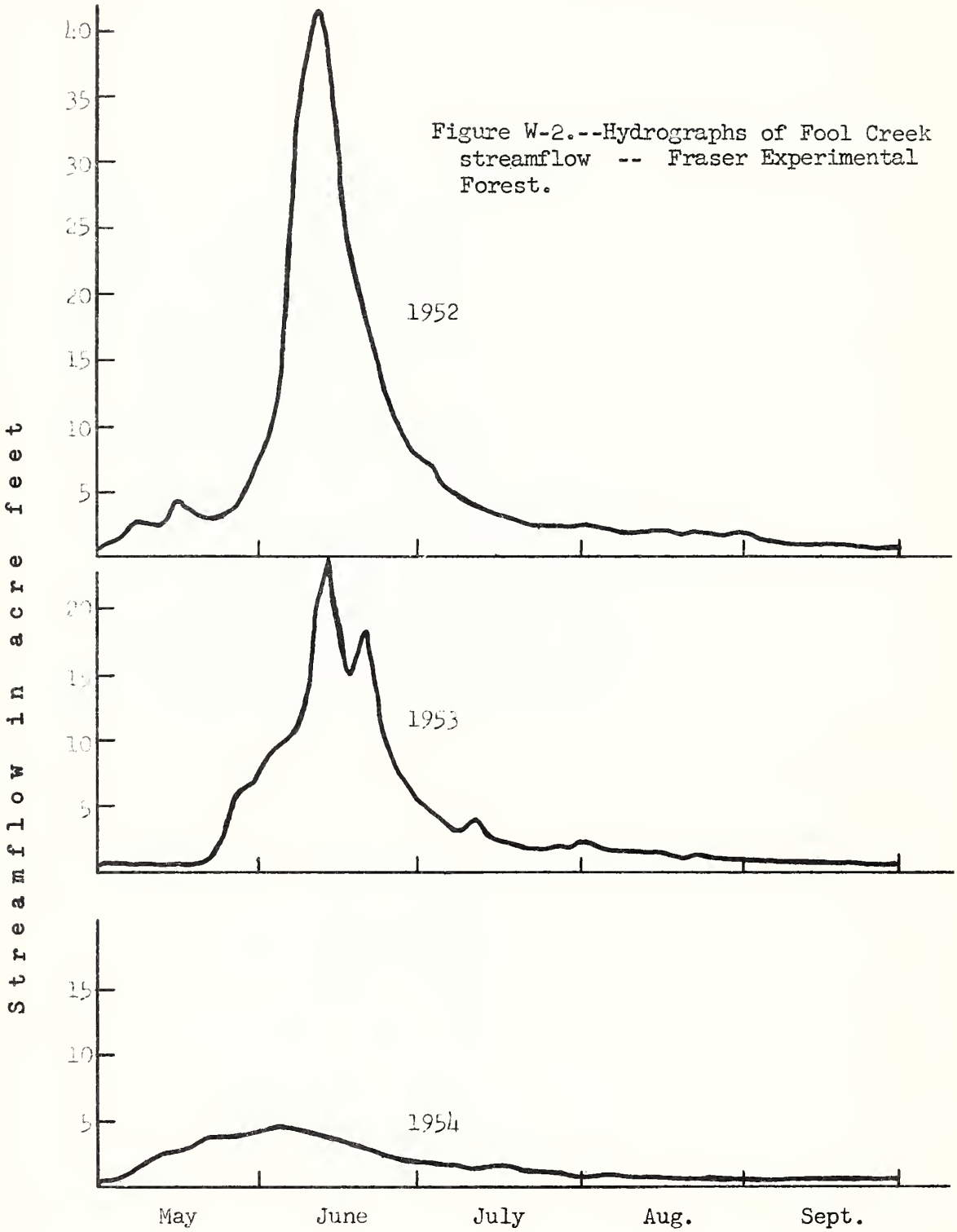


Figure W-2.--Hydrographs of Fool Creek streamflow -- Fraser Experimental Forest.

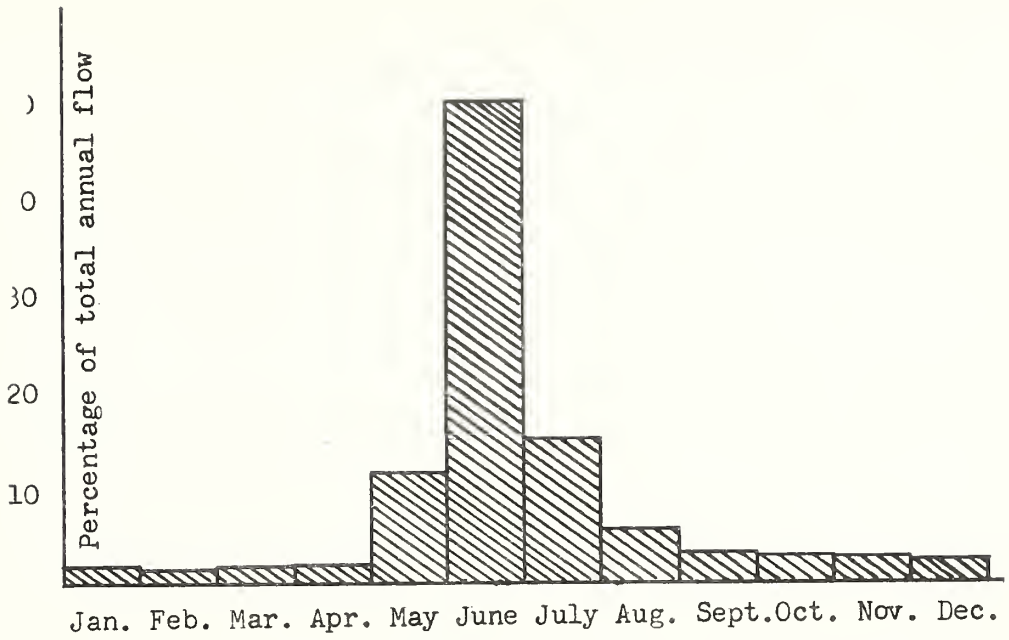


Figure W-3.--Monthly distribution of Fool Creek Streamflow

1954 was year of least streamflow

Streamflow in 1954 from Fool Creek, a 710-acre watershed on the Fraser Experimental Forest, was one-half the 15-year average as a result of very little snow. Melting began early in the season but there wasn't enough snow to give the usual spring peak. Instead of 50 percent of the runoff, only 27 percent was measured in June. Total flow for the year was 363 acre-feet compared with the average of 760 acre-feet.

The highest streamflow year was 1952 when as a result of a record snow pack the total flow was 1,068 acre-feet. A real peak occurred during June when 50 percent of the year's flow came off in a 19-day period. Figure W-3 shows how streamflow was distributed during the years 1952, 1953, and 1954. This 3-year period is of exceptional interest because it includes 1 year that represents the average of the 15-year record and also the years of highest and lowest flow.

Chaparral roots penetrate to depth of 16 feet

Examination of roots exposed by mining road construction in central Arizona indicates that roots of some chaparral shrubs penetrate more deeply than the native grasses.

Species	Maximum depth of roots, feet	Remarks
Grasses		
Bullgrass	6	Stony loam soil
Sidecats grama	$2\frac{1}{2}$	Diabase soil--most roots within 10-16 inches
Cane bluestem	4	Diabase soil
Shrubs		
Turbinella oak	10	In cracks and fissures in disintegrated rock
Manzanita	7	Plant 3 feet tall with crown 5 feet in diameter
Hollyleaf redberry buckthorn	11	Plant 8 feet tall with crown 10 feet in diameter
Emory oak	10	1/8-in. diameter rootlets in fissures
Beargrass (Nolina)	8	Most roots within 30 in. of ground surface
Desert ceanothus	12	1/16-in. diameter roots in disintegrated diabase
Unidentified roots	16	In cracks in quartzite rock

In several instances, roots of shrub species were found to completely occupy the soil in openings 20 to 30 feet across. These roots grew more or less parallel to the ground surface and filled the top 5 feet of soil. The shrub roots extended downward through cracks and fissures in underlying rock. In one case, only 12 inches of soil overlaid fractured quartzite bedrock but at a depth of 16 feet there was a 2-inch wide band of disintegrated material. Within this layer, numerous roots had reached that depth by forcing through narrow vertical cracks. Roots 3/16-inch thick and 1 inch wide were frequently present in the cracks.

Figure W-4.— Alternate strip cutting on Fool Creek watershed in Colorado. One-half of the area will be cut to determine the effect of this silvicultural system on streamflow. Strips are about 6 chains long and 1, 2, 3, and 6 chains wide. Fence posts and pulpwood are harvested. The foreground shows a strip on which logging has been completed. Snow surveys will be made to learn how strip width and orientation control snow accumulation and melt.

Figure W-5.— A view of a portion of the Fool Creek watershed, showing the patchwork pattern of openings created by the alternate strip cutting.

Abundance and depth of spruce and aspen roots similar

Aspen and spruce roots were found to be abundant to a depth of 3 feet, scattered between 3 to 5 feet, and scarce at 7 feet on deep soils developed from rhyolites in western Colorado. Thurber and Idaho fescue roots reached depths of 6 feet in adjacent openings. Roots of Gambel oak were more abundant at lower depths than any other species but were rarely found below $7\frac{1}{2}$ feet.

Relative water use by spruce, aspen, and grass is of considerable interest and importance to watershed management. Depth of root penetration is one of the factors that control the amount of soil moisture withdrawn by plants.

Lovegrass and mulch continue to control erosion

Mulch and reseeded grass (Lehmann and Boer lovegrass) continue to effectively reduce erosion on experimental watersheds in the granitic soil type near Roosevelt Dam in Arizona. An extensive system of gullies was present in 1926 when the area was fenced for study. Even though plant cover on the watershed improved, the gullies remained raw and continued to contribute excessive amounts of sediment. During 1953, 4 of the 7 watersheds were rehabilitated by sloping and reseeding gullies, and by replacing chaparral with volunteer and introduced grasses. As indicated by the following tabulation, the mulch and improved grass conditions are effectively reducing erosion on these small watersheds:

Watershed treatment	Size	Aspect	Grass density 1954	Sediment yield		
				Average 1931-41	Summer 1954	Summer 1955
	acres		percent	Tons per sq. mile per year		
Reseeded 1953	0.37	South	0.62	3,144	14	35
Reseeded 1953	.49	South	.51	1,792	52	26
Reseeded 1953	.43	North	.60	3,060	60	30
Reseeded 1953	.49	North	.26	4,212	52	32
Stabilized 1934	.59	South	.17	1,712	27	22
Protected since 1926	1.23	South	.07	6,281	1,220	1,447
Protected since 1926	1.05	North	.12	4,538	6,100	3,401

Gullies are still critical erosion hazards. Only heavy storms, yet to be experienced, will test the efficiency of the mulch and perennial grass as erosion control measures.

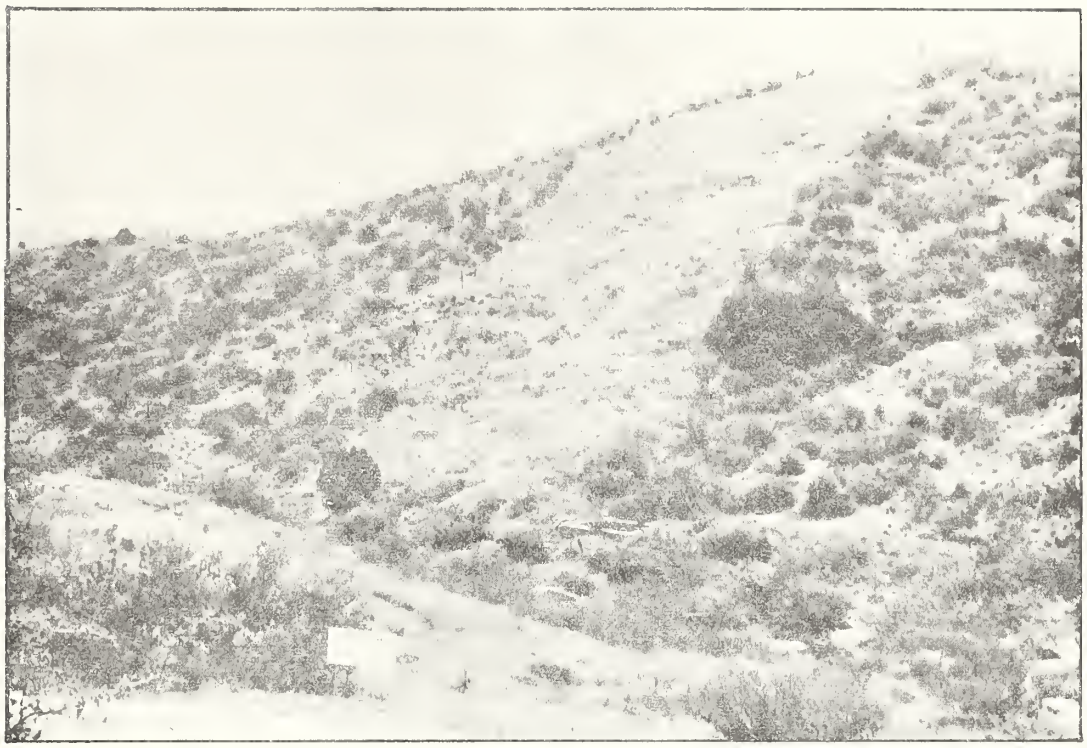


Figure W-6.— A view of one of the four Summit plots on which brush was dug up and lovegrass was sown. Undisturbed brush was left on both sides. In the 2 years since grass was established, sediment movement has been reduced about to one-hundredth of the previous rate.

Figure W-7.— On June 17, 1947, a lightning-caused fire swept over 7,200 acres of chaparral in the Four Peaks country near Roosevelt Dam in Arizona. This picture was taken July 2, 1947. There was nothing left alive above-ground. Charred stems and a layer of ashes were all that remained of the former plant cover.

Figure W-8.— This picture was taken August 28, 1947, just 8 weeks after figure W-7 and from the same spot. Summer rains have hit, and with protective litter and vegetation gone, have rilled and gullied it. The channel in the foreground is choked with soil washed from upslope and now on the way to Roosevelt Reservoir. Brush has begun to sprout and some new stems are already a foot long.

Figure W-9.-- The same scene 5 years later, September 1952. The chaparral plants have sprouted vigorously. Practically all the grass that once grew here has been killed by the fire. Shrub species, however, have made a strong comeback, but there are only a few herbaceous plants growing between the shrubs.

These three pictures show some of the difficulties to be overcome and problems to be solved in using fire as a tool to increase forage. At times, fire may prove to be a useful tool in the management of brush-covered lands, but it is more than a business of just lighting a match during dry weather.

History of a wildfire points up problems in use of fire for conversion of brushlands

The accompanying pictorial history shows what usually happens after wildfire. Soil is bared to rainfall, and damaging erosion is a consequence. Most of Arizona's brush species such as scrub oak come back quickly after fire. Grasses recover slowly and lose out to the vigorous brush. The end result in this sequence is a period of erosion and then the brush is back again. Fire may prove to be extremely useful in improving chaparral areas, but it will take more knowledge than is now available to use it properly.

Foliage area of ponderosa pine trees

The surface area of foliage is useful for a better understanding of tree growth, interception of precipitation, light absorption of forest canopies, and for such purposes as calculating requirements for foliage sprays used in insect control. At the Sierra Ancha Experimental Forest in Arizona, the surface area of foliage was found to be related to tree diameter as shown by the equation below, with diameter in inches and foliage area in square meters.

$$\text{Log foliage area} = 1.80 \ (\log \text{d.b.h.}) + 0.14$$

Examples of foliage area according to this formula are:

Tree d.b.h. inches	Surface area of foliage square meters
4	1.6
8	5.8
12	11.8
16	20.0
20	30.2
24	41.6
28	55.5

Summer rains wet only shallow soil layer in pinyon-juniper type

During the summers of 1953 and 1954, moisture did not penetrate below a depth of 12 inches under either pinyon trees or blue grama grass on study plots at 7,300 feet elevation in the Manzano Mountains southeast of Albuquerque, New Mexico. In the wetter summer of 1955, after 6.5 inches of rain fell between mid-July and mid-August, moisture reacned the $16\frac{1}{2}$-inch depth under pinyon and a depth of $13\frac{1}{2}$ inches under blue grama. On September 24, 2.5 inches of rain resulted in moisture penetrating to a depth of 30 inches under pinyon. A higher infiltration rate under pinyon is the cause for the greater penetration of moisture.

The amount of rain that entered the soil was found to be a function of the capacity of the surface soil to store moisture. The deeper penetration of moisture under pinyon is attributed to a greater capacity of the soil there for moisture storage.

Comparative infiltration rates for wet and dry soil are given below:

	Dry surface soil	Surface soil at field capacity
	- - inches per hour - -	
Under pinyon trees	1.9	1.9
Blue grama cover	1.1	0.6
Bare soil	1.0	0.5

More careful tests to determine the change in infiltration capacity with change in soil moisture were made in a blue grama grass-covered area in September 1955 with the following results:

Soil moisture at beginning of test, surface 12-inch layer (percent by weight)	Infiltration rate (inches per hour)
6.5	1.42
12.2	1.13
17.8	.95
22.7	.54

The precipitation record for the study period is summarized in the following table:

Period	Seasonal Precipitation			Days with precipitation of 0.01-inch or more		
	1953	1954	1955	1953	1954	1955
	- - - inches - - -			- - - number - - -		
Jan.-Mar.	-	2.61	0.66	-	10	9
Apr.-June	3.94	2.85	1.63	7	10	8
July-Aug.	5.84	5.00	8.43	12	22	25
Sept.-Oct.	.68	2.72	3.19	3	9	3
Nov.-Dec.	2.36	1.10	.95	8	3	3
Total	-	14.28	14.86	-	54	48

The size of storms and the rate with which precipitation falls are of considerable importance. Evaporation losses take nearly all of the light showers. During summer, more than 0.25-inch of rain in a day is required to add measurable moisture to the surface inch of soil under pinyon.

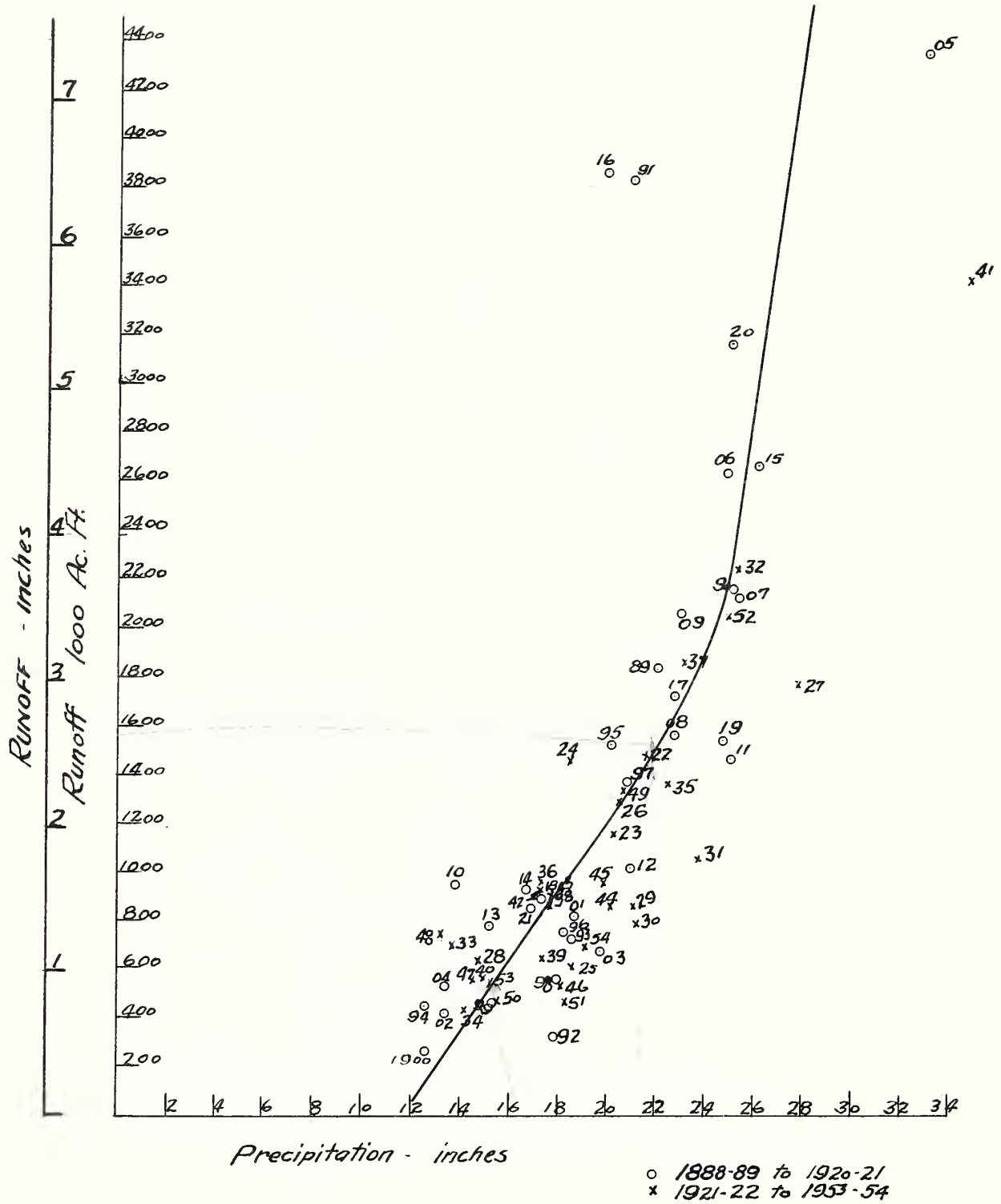


FIG. W-10.-- RAINFALL & RUNOFF SALT RIVER SYSTEM 1889-1954

The amount of moisture received per day from the 132 storms recorded, and the maximum rates of rainfall measured, are shown below.

Daily moisture		Rainfall	
Precipitation class (inches per day)	No. of days	No. of minutes	Inches per hour
0.01 - 0.25	86	5	4.9
0.26 - 0.50	26	10	4.9
0.51 - 1.00	13	15	3.8
1.00 plus	7	30	2.7
		60	1.6

Rainfall and runoff for the Salt River system

Trends in the proportion of precipitation that appears as streamflow receive considerable attention in the Southwest. Rapid increases in population and below normal precipitation of recent years put increasing pressures on water supply and cause concern for the future. A fundamental characteristic of southwestern climate is the great variation of rain and snow from year to year. There is a tendency for wet or dry years to be grouped, but the pattern is extremely erratic. Streamflow is, of course, strongly related to total precipitation and to the seasonal distribution of precipitation over the watershed.

The search for trends in the relationship of streamflow to precipitation is handicapped by scanty records. However, it is possible to piece together information on the combined flow of the Salt River system, which includes the Salt, Verde, and Tonto river drainage basins in Arizona.

Streamflow records are based on records published by the U. S. Geological Survey. Some of the stream gages have been moved during the period, and records for recent years are for slightly smaller areas. Rainfall is based on Weather Bureau records for Flagstaff, Fort Apache, Granite Reef, Natural Bridge, Pinal Ranch, and Prescott. Incomplete portions of the record were filled out by using relationships with nearby stations.

Figure W-10 is a plotting of annual streamflow against precipitation for the years 1889 through 1954. The years before 1921 are shown by the small circles and those after 1921 as the crosses. The curve fitted to the plotted values indicates the average relationship of runoff to precipitation. On this average, 16 inches of precipitation will yield about 450,000 acre-feet of

runoff, and 22 inches about 1,500,000 acre-feet. The deviation of points from this curve may be caused by (1) unusual distribution of rainfall within individual years, (2) by the failure of the 6 rain gages used to give a good sample of precipitation over the watershed, or (3) by any changes on the watershed which altered the proportion of precipitation continuing to runoff.

Study of the figure will show that there are about as many crosses and circles on each side of the average line. This would indicate that there isn't much difference in the proportion of rainfall that reached the stream before or after 1921. It is remarkable how closely 1899 and 1950 compare and also how 1954 checks with 1893 and 1903. Streamflow was least in 1900 and most in 1905. Streamflow in the years 1916 and 1891 was extremely high in proportion to precipitation. The cause is believed to be the concentration of precipitation into a brief period both of those years. Most of the runoff in those years came from one large storm. In 1941, the entire winter period was wet and temperatures were above normal.

Figure W-11 is a plotting of rainfall and runoff for 5-year periods. This smooths out the year-to-year variation by combining wet and dry years. The averages plot close to a straight line, indicating a fairly consistent relationship of streamflow to precipitation for the entire period of record. The least runoff in relation to precipitation was between 1925 to 1929. The most was between 1890 to 1894. The years 1920-1934 show below normal relationships but from 1930 to 1949 points fall on or above the line. The period 1950 to 1954 is only slightly below the line. This figure shows that the primary reason for low streamflows in recent years is deficient precipitation over the watershed.

Streamflow depends on cool season precipitation

Records for the past 20 years show how important winter precipitation is to streamflow for a 700-acre watershed in the Sierra Ancha Mountains of Arizona. This watershed lies between 5,400 and 7,400 feet in elevation and has a cover of chaparral on lower slopes with ponderosa pine at its head. Figure W-12 shows graphically how runoff is related to precipitation for the year and for the winter and summer season. Winter precipitation contributes only two-thirds of the annual total but causes nine-tenths of the total runoff. In only 1 year of the 20 did summer streamflow exceed that in winter. In one other year almost 50 percent of the year's flow came in summer. These exceptions were the years 1951 and 1946 when very heavy general rains fell during the summer.

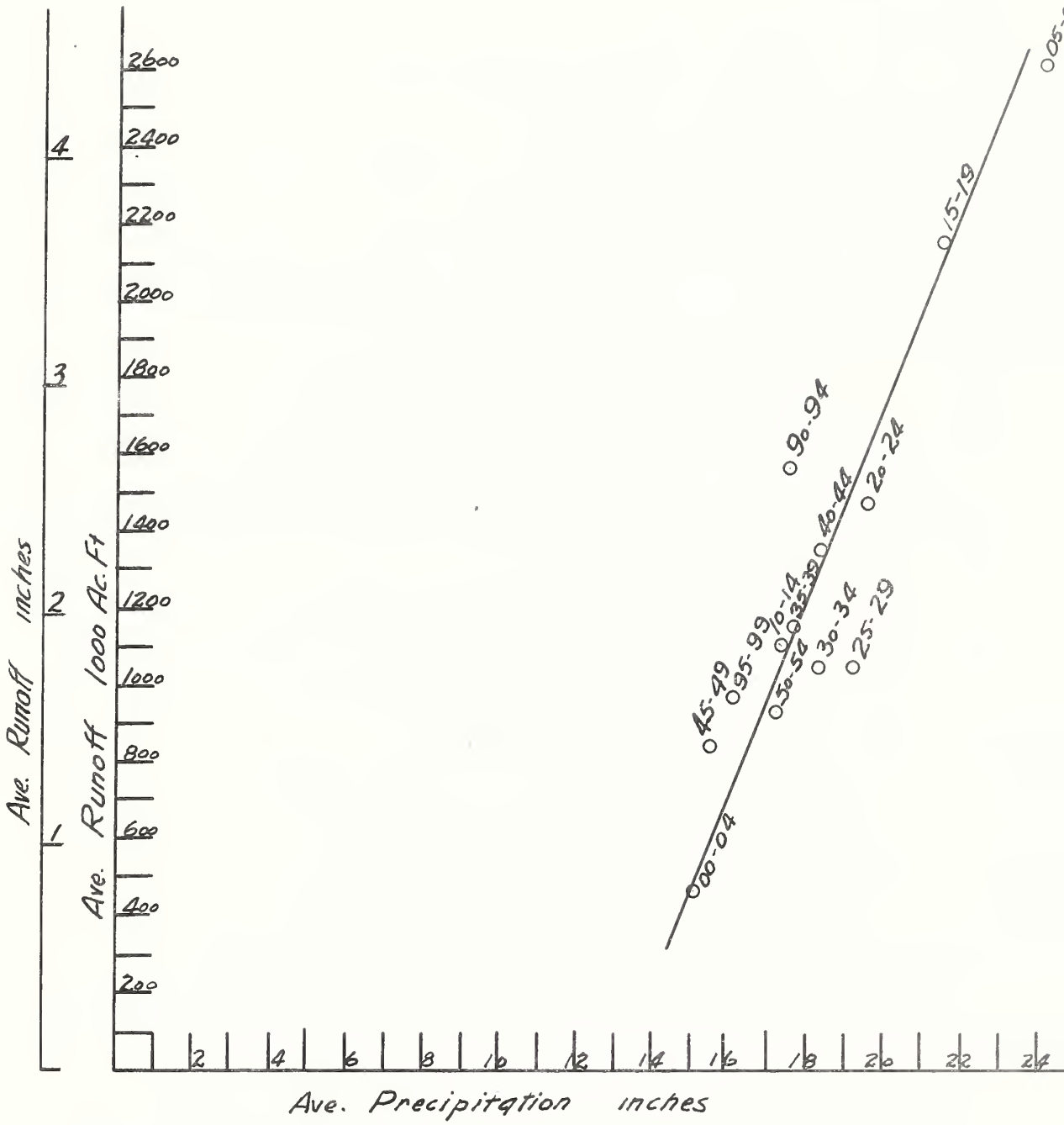
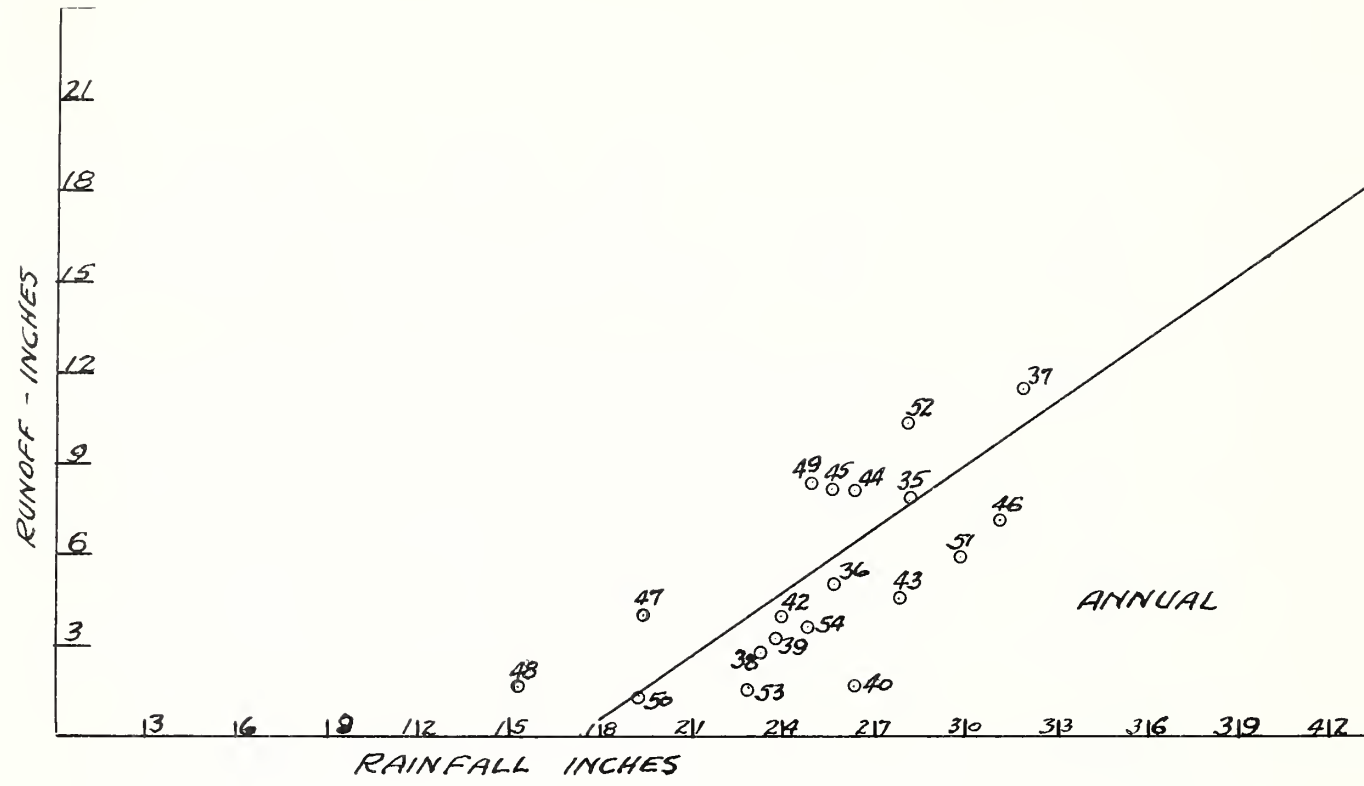
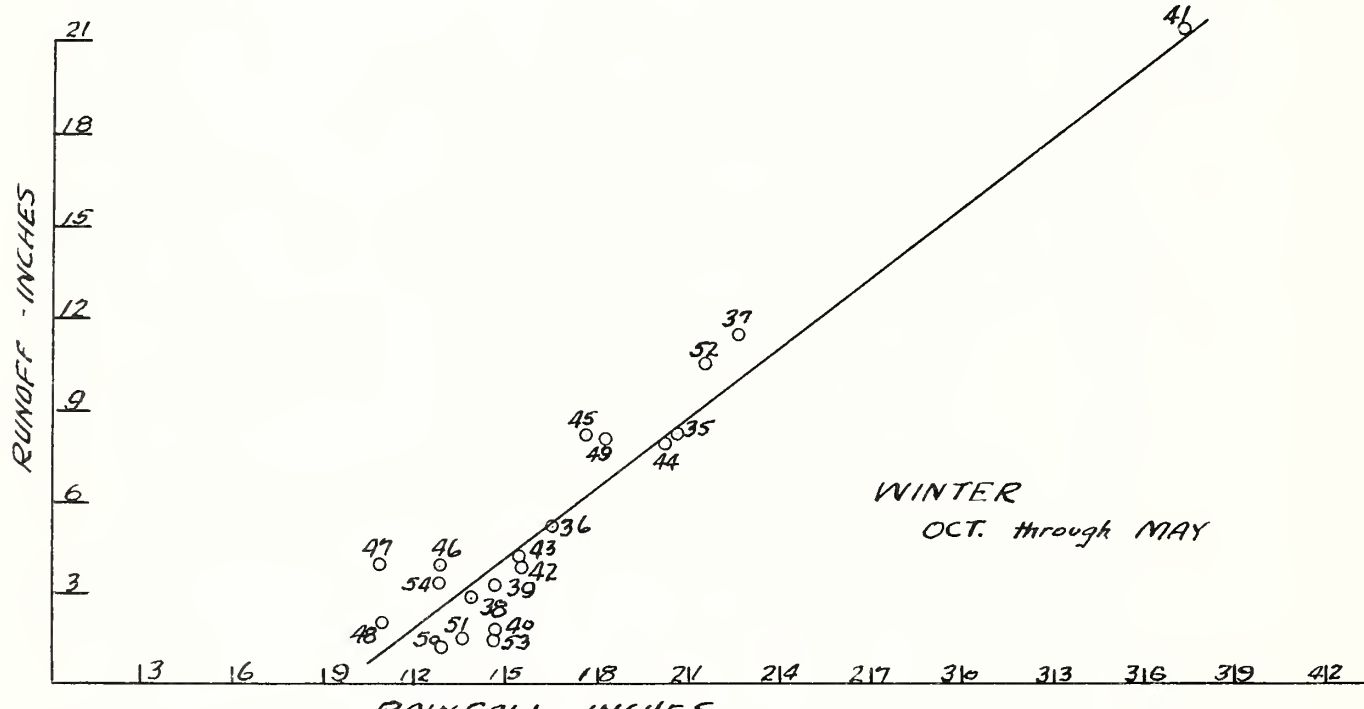


FIG. W-11:- RAINFALL & RUNOFF SALT RIVER SYSTEM
5 YEAR AVERAGES 1890-1954





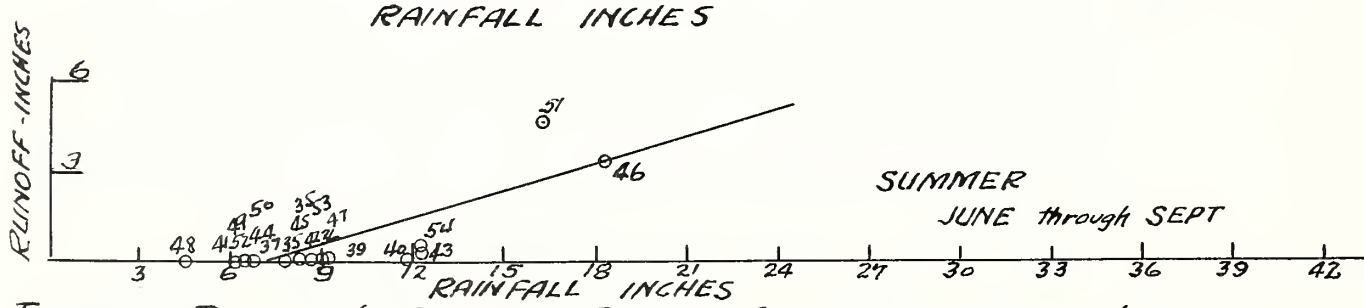


FIG. W-12.--RAINFALL & RUNOFF PARKER CREEK WATERSHED (700 Ac.)

Hydrologic aspects of beaver habitat studied

Beaver habitat is limited to perennial streams having an adequate food supply and certain required physical characteristics. In the mountains, beavers may have a strong influence upon the stream's hydrologic behavior and physical stability.

A study in 1954-55 determined the effect of beavers on (1) erosion stability of soils, stream bottoms, and stream channels, and (2) the steepness of slopes, valley grades, valley width on sites occupied by beavers. Knowledge of the interaction between beavers and their physical environment would form the basis for improved management of mountain streams and of beavers as fur-bearing animals.

The study showed that beavers are selective in choosing an area for a home. They do not permanently occupy areas where the stream grade exceeds 15 percent. The percentage of streams of different grades occupied by beavers was found to be:

Valley grade	Percentage occupied by beaver
1-3%	37
4-6%	30
7-9%	18
10-12%	9
13-15%	6

The width of the valley appeared to have little direct effect on beaver sites; however, valley width was found to be indirectly related to valley grade, that is, as the grade increased, the width of the valley decreased.

Steepness of slopes or other characteristics of upland areas adjacent to the valley floor had no influence on beaver occupancy in the valley. Likewise, beavers occupy territory in all kinds of soils and rock types.

Beavers have an important effect upon the stability and present condition of stream channels. Unmanaged beavers abandon an area after the food supply is exhausted. Their dams then

deteriorate, often resulting in the development of deep gullies down channels that were formerly protected by dense, stream-bottom vegetation. This destruction is much more severe in some kinds of soils and rocks than in others. Destruction is greatest in shale rocks and soils and most stable in glacial till deposits.

A site suitability classification was developed from the study. Although much remains to be learned about the influence of beavers on the hydrology of mountain streams, it is evident that a stabilized beaver population in certain kinds of valleys and in some kinds of rock materials can do much to stabilize land conditions and enhance other wildlife resources.

Wild land survey methods and techniques

Studies were begun in Colorado to develop land survey methods and techniques best suited for the development of land management plans for forest and range lands. These lands differ markedly from cultivated lands in physical makeup and use potentials and require a different approach in fact-finding techniques. The project involves the collection and analysis of data and the evaluation of the suitability and productivity levels of the different soils for the important uses of forest and range lands. This work will form the basis for multiple land use management based upon the potentialities of the land to produce.

Material developed for use in training in forest and range soils

In order to develop an appreciation of the importance of soils and how to use them in wild land management, information for an advanced training course in Forest and Range Soils was developed. The course consists of (1) a review of the fundamentals of soil fertility, moisture, and classification, (2) principles of erosion, and (3) land use classification for the several uses to which wild lands are put. Emphasis is placed on those features of soils, rocks, and land forms which appear to be most significant to wild land management. This material will be further processed into a handbook or manual on soils and soil problems for use by forest rangers and other land managers. The manual will emphasize practical, interpretive information on soils.

FOREST BIOLOGY

In cooperation with
U. S. Fish and Wildlife Service

Colorado sponsors a study of range rodents

The State of Colorado appropriated funds, which became available in July, for a cooperative gopher control study. The Rocky Mountain Forest and Range Experiment Station and the U. S. Fish and Wildlife Service shared in its planning and execution. The study has three main objectives: to control gophers by chemical means, to control gophers through their biological or environmental weaknesses, and to measure the relationships between gophers and range and watershed lands.

Poisons were tested on several hundred gophers. Search is now being conducted for a residual poison that will remain effective for several months under snow. A study of census methods reveals that slow, laborious trapping is required to estimate populations, which may run as high as 20 per acre. Gophers in Colorado evidently breed but once a year. A quarter-acre gopher exclosure for long-time studies was built on Black Mesa in September. The type of exclosure planned for the future will probably consist of a low drift fence in a 5-acre zone kept free of gophers in summer by poisoning and trapping.

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PUBLICATIONS

Forest Management Research

ALEXANDER, R. R., and BUELL, J. H.
Determining the direction of destructive winds in a Rocky Mountain timber stand. Jour. Forestry 53 (1): 19-23. January 1955.

Tallies of the bearings from root to top of windthrown trees in a 714-acre watershed indicated that direction of destructive winds is not influenced by topography. The method described is useful for determining direction of high winds, and so for orienting cutting strips.

BUELL, J. H., joint author with HAYES, G. L.
Trees also need water at the right time and place. U. S. Dept. Agr. Yearbook 1955: 219-228. 1955.

Outlines the physiological processes requiring water in trees, the relation between the distribution of forests and the moisture provinces of the earth, and the ways in which moisture in the environment may be manipulated in the management of forests.

GAINES, E. M., joint author with KALLANDER, H. R., and WEAVER, H.
Additional information on prescribed burning in virgin ponderosa pine in Arizona. Jour. Forestry 53 (10): 730-731. October 1955.

Indicates the extent to which wildfires may have been reduced, for a 3-year period following controlled burning of 65,000 acres on the Fort Apache Indian Reservation.

READ, R. A.
Grading of transplants may improve initial survival of ponderosa pine in Plains windbreaks. Research Note No. 16. 2 pp. June 1955.

First-year survival of graded, hand-planted, 2-1 ponderosa pine at 8 Nebraska locations average 90 percent, in contrast to 42 percent for ungraded, hand-planted stock of same age and seed source.

_____
Status of the Great Plains shelterbelts. Yale Forest School News 53 (4): 67-74. October 1955.

Windbreak effectiveness and species survival and height development in the past 10 years was evaluated in approximately 900 shelterbelts from North Dakota to northern Texas.

Forest Disease Research

ANDREWS, S. R.
Red rot of ponderosa pine. U. S. Dept. Agr. Agr. Monog. No. 23. 31 pp. March 1955.

Discusses the taxonomy, genetics, biology, economic importance, and control of the red rot fungus, Polyporus anceps.

DAVIDSON, R. W.
Wood-staining fungi associated with bark beetles in Engelmann spruce in Colorado. Mycologia 47 (1): 58-67. January-February 1955.

Notes on four bluestain fungi associated with beetle-killed spruce wood. Three new species are described of which Leptographium engelmanii is most common.

GILL, L. S., joint author with LEAPHART, C. D.
A study of lesions associated with pole blight. Forest Science 1 (3): 232-239. September 1955.

Shows that the bark lesions associated with the pole blight disease of western white pine originate after trees have suffered a marked growth reduction.

Forest Utilization Research

KOTOK, E. S.
Estimated paper consumption in nine central Rocky Mountain and Plains States area. Research Note No. 18. 2pp. December 1955.

Shows paper and paperboard consumption, by major products, and the proportion of the requirements met by production within the nine-State area.

_____ and MYERS, C. W.
An estimate of residues at a small sawmill in the Black Hills. Research Note No. 17. 6 pp. August 1955.

The net volume of lumber that is recovered from the sawing of a thousand board-feet of sawlogs is shown along with the corresponding volume of the various types of mill residues.

STATION STAFF
This is the skyline-crane logging system. 11 pp. September 1955.

The key features of the equipment and installation are described to assist in handling demonstrations. Regulations regarding safety are also included.

Range Management Research

ARNOLD, J. F.
Juniper control. Ariz. Cattlelog 10 (9): 44-50. May 1955.

Describes methods and recent progress in controlling juniper in Arizona.

_____
Plant life-form classification and its use in evaluating range conditions and trend. Jour. Range Mangt. 8(4): 176-181. July 1955.

Classifies plants in the ponderosa pine zone of northern Arizona into eight life-form groups; discusses he use of this classification as an aid in judging condition and trend of ranges in the Southwest.

_____
Juniper control as a range-improvement practice in central Arizona. In Ranch Day, held at Jornada Experimental Range, Las Cruces, New Mexico, October 1955. pp. 7-10a.

Describes methods of juniper control -- hand clearing, cabling, dozing, burning -- and resultant benefits.

_____ and SCHROEDER, W. L.
Juniper control increases forage production on the Fort Apache Indian Reservation. Station Paper No. 18. 35 pp. December 1955.

Evaluates effects of juniper control on seven different sites during periods of 2 to 14 years in Arizona.

BOHNING, J. W.
The effects of prescribed burning a grass shrub range on burroweed, cholla, pricklypear, mesquite, and other shrubs. In Ranch Day, held at Jornada Experimental Range, Las Cruces, New Mexico, October 1955. pp. 11-13.

Reports results of recent tests of prescribed burning on the Santa Rita Experimental Range in Arizona.

GLENDENING, G. E. and PAULSEN, H. A., JR.
Reproduction and establishment of velvet mesquite as related to invasion of semidesert grasslands. U. S. Dept. Agr. Tech. Bul. No. 1127. 50 pp. October 1955.

A comprehensive bulletin on the ecology of mesquite and its relation to range management.

HURD, R. M.
Effect of 2,4-D on some herbaceous range plants. Jour. Range Mangt. 8 (3): 126-128. May 1955.

Forb herbage production on rod-square plots decreased 86 percent 1 year after spraying. Geum trifolium and Lupinus sericeus decreased markedly but some forbs showed no effects.

JOHNSON, W. M., joint author with HULL, A. C., JR.
Range seeding in the ponderosa pine zone in Colorado. U. S. Dept. Agr. Cir. No. 953. 40 pp. February 1955.

Presents recommendations on species to seed and methods of seeding deteriorated ranges; also tells how to graze reseeded areas.

PAULSEN, H. A. JR.
Changes in grazing capacity on the Jornada Experimental Range. In Ranch Day, held at Jornada Experimental Range, Las Cruces, New Mexico, October 1955. pp. 4-6.

Summarizes findings from 38 years of grazing research in southern New Mexico.

REID, E. H.
Range improvement and management in the southern Great Plains area. Western Farm Econ. Assoc. Proc. pp. 4-9. 1954. (Not listed in Station's 1954 Annual Report)

A general discussion of range-management problems in Colorado, New Mexico, and in the western parts of Kansas, Oklahoma, and Texas; includes forage production, reseeding, noxious plant control, drought, and grazing.

REYNOLDS, H. G.
Do you use fully the levers at hand to obtain best livestock distribution. Western Livestock Jour. 33 (8): 38-39, 109-113. January 1955.

Discusses the use of fencing, watering, salting, and other practices to get better livestock distribution on range.

SPRINGFIELD, H. W., joint author with LAVIN, F.
Seeding in the southwestern pine zone for forage improvement and soil protection. U. S. Dept. Agr. Handb. 89 52 pp. October 1955.

Describes methods of seeding, evaluates grass species, offers suggestion on grazing management on newly seeded stands, and discusses cost and return from seeding rundown ranges. Also explains how to obtain soil protection by seeding within timberlands disturbed by logging, fire, or construction.

_____, joint author with BRYAN, H. M.
Range management in Iraq -- findings, plan and accomplishment. Jour. Range Mangt. 8 (6): 249-256. November 1955.

Describes work of the Foreign Operations Administration (now International Cooperation Administration) on range improvement in Iraq.

STATION STAFF
Want to buy grass? N. Mex. Agr. Expt. Sta. Press Bul. No. 1136. 2 pp. March 1955.

Brief, pictorial summary of successful range reseeding in New Mexico.

Watershed Management Research

FLETCHER, H. C., and ELMENDORF, H. B.
Phreatophytes -- a serious problem in the West. U. S. Dept. Agr. Yearbook 1955: 423-429. 1955.

Discusses important phreatophyte species, their effect on water resources, and methods of control.

_____ and RICH, L. R.
Classifying southwestern watersheds on the basis of water yields. Jour. Forestry 53 (3): 196-202. March 1955.

Summarizes 20 years of research in water yields on the Sierra Ancha Experimental Watershed near Globe, Arizona. Discusses the influence of precipitation, evapotranspiration, and other factors on seasonal water yields. Groups water-yielding area into three classes: high, intermediate, and low.

GOODELL, B. C.
Hope for aging snow surveyors or snow surveying from skis to wheel chair. The Snow Surveyors' Forum, 8th An. Ed: 38-40. 1954. (Not listed in Station's 1954 Annual Report)

A humorous history of snow surveying on the Fraser Experimental Forest, Colorado.

_____ and WILM, H. G.
How to get more snow water from forest lands. U. S. Dept. Agr. Yearbook 1955: 228-234. 1955.

Describes the ways that forests affect water yield from snow; also reviews experiments that show the magnitude of these effects.

HOOVER, M. D.
Mountain watersheds and Great Plains agriculture. Western Agr. Econ. Assoc. Proc., pp. 1-3. 1954.
(Not listed in Station's 1954 Annual Report)

Reviews watershed-management possibilities in Colorado mountains and the need for economic evaluation of water resources.

_____, joint author with TROUSDELL, K. B.
A change in ground-water level after clearcutting of loblolly pine in the Coastal Plain. Jour. Forestry 53 (7): 493-498. July 1955.

In Coastal Plain of Virginia, clearcutting causes increase in ground-water elevation.

LOVE, L. D.
The effect on streamflow of the killing of spruce and pine by the Engelmann spruce beetle. Trans. Amer. Geophys. Union 36 (1): 113-118. February 1955.

Statistical analyses were made to compare streamflow and water content of snow for the 762 square-mile

drainage basin of White River with similar measurements made for 206 square-mile drainage basin of the Elk River. The analyses showed that the flow of White River increased after the beetle outbreak. The average annual streamflow increased by 1.22 inches during 1941-46, and by 2.28 inches during 1947-51 as compared to the period 1937-40 after adjustment was made for climatic fluctuations.

_____, joint author with RENNER, F. G.
Management of water on western rangelands. U. S. Dept. Agr. Yearbook 1955: 415-423. 1955.

Discusses the importance of holding rain where it falls for the growth of forage plants for livestock; also summarizes some of the supplemental measures which might be applied to rangelands to increase water absorption and forage production.

Forest and Range Soils

RETZER, J. L.
Physical environmental effects on beavers in the Colorado Rockies. West. Assoc. State Game and Fish Comm., 35th Annual Conf. Proc. 279-287. 1955.

Discusses physical suitability of mountain streams for beaver occupancy and the effect of beavers on the stability of those streams.

_____ and COLMAN, E. A.
Soil surveys on forest and range lands. U. S. Dept. Agr. Yearbook 1955: 242-246. 1955.

Discusses the importance of soil surveys of wild lands as a basis for land-use planning.

Forest Biology

SCHEFFER, V. B.
Son exclusivou del oeste de Norteamerica los micromonticulos de tipo Mima? (Are earth mounds of the Mima type confined to western North America?) Investigaciones Zoological Chilenas, Santiago, 2 (6): 89-94. October 1954.
(Not listed in the Station's 1954 Annual Report)

Describes Mima-type mounds in western North America and asks for reports on similar phenomena in other parts of the world.

_____
Body size with relation to population density in mammals. Jour. Mammalogy 36 (4): 493-515. November 1955.

Presents original data on body size with relation to density of population in the Alaskan fur seal; also reviews similar work on the brown rat, house mouse, vole, muskrat, gray squirrel, raccoon, deer, and man.

General

PRICE, RAYMOND
The use of arid lands. New Outlook 8 (6): 78-82. June 1955.

(Excerpted from a paper presented at the International Arid Lands Symposium of the Amer. Assoc. Adv. Sci. held at Albuquerque, New Mexico, April 26-28, 1955.)

Discusses critical problems of land use in the arid sections of southwestern United States as related to forage resources, drought, seasonal grazing, reseeding, woodland management, and water supply.

SHAW, E. W.
Review of "The wilderness world of John Muir" by Edwin Way Teale. Jour. Forestry 53 (1): 37-38. January 1955.

_____
Ten commandments for technical writers.
Science 121 (3146): 567. April 15, 1955.
Reprinted in Jour. Forestry 53 (9): 673. September 1955.

Briefly outlines common pitfalls in technical writing.

_____
Tree's biography is written. West. Conserv. Jour. 12 (4): 1-2. July-August 1955.

Shows management possibilities by tracing origin, growth, and development of a young Douglas-fir stand near McCleary, Washington.

STATION STAFF
Annual Report, 1954. Rocky Mountain Forest and Range Experiment Station. 57 pp. 1954.

Outlines research progress at the Station during 1954.

Logs in the sky. Empire Magazine (Denver Post). September 18, 1955. pp. 35-36.

Popular article with photographs describing the skyline-crane logging system recently installed at the Fraser Experimental Forest in Colorado.

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Agriculture-Colo.A&M,Ft.Collins

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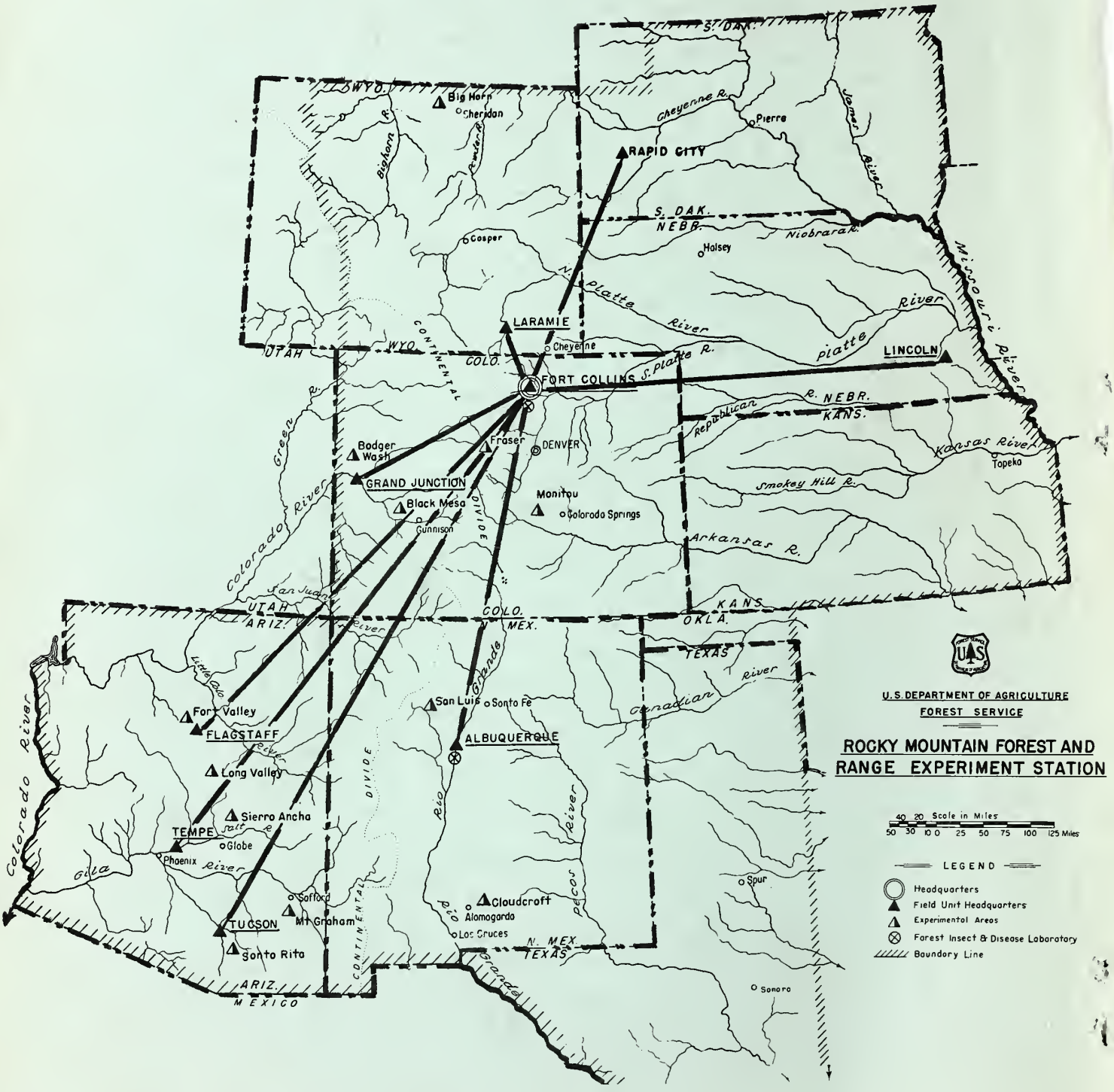

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

40 20 Scale in Miles
50 30 10 0 25 50 75 100 125 Miles

LEGEND

- Headquarters
- Field Unit Headquarters
- Experimental Areas
- Forest Insect & Disease Laboratory
- Boundary Line